AUDELS

PLUMBERS
AND
STEAM FITTERS
GUIDE #1

Plumbers Yarning and Caulking Tools.

No. 1, yarning iron ¾ x 4; 2, long regular iron ¾ x 3½; 3, regular iron ¾ x 2½; 4, finishing iron ¾; 5, throat iron ⅝; 6, cold chisel ¾; 7, R.H. offset iron ¾; 8, L.H. offset iron ¾; 9, ceiling iron ⅓ x ⅝; 10 spring yarning iron ½.

"BY HAMMER AND HAND ALL THINGS DO STAND"

AUDELS
PLUMBERS
AND
STEAM FITTERS
GUIDE #1

A PRACTICAL ILLUSTRATED TRADE ASSISTANT AND READY REFERENCE

FOR

MASTER PLUMBERS, JOURNEYMEN AND APPRENTICES
STEAM FITTERS, GAS FITTERS AND HELPERS,
SHEET METAL WORKERS AND DRAUGHTSMEN
MASTER BUILDERS AND ENGINEERS

EXPLAINING IN PRACTICAL CONCISE LANGUAGE
AND BY WELL DONE ILLUSTRATIONS, DIAGRAMS,
CHARTS GRAPHS AND PICTURES THE PRINCIPLES
OF MODERN PLUMBING PRACTICE

BY

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Foreword

These Guides give first hand reliable practical information in clear and concise form. They illustrate **Plumbing** in its many practical applications in the clearest and plainest manner and in a way not to discourage the searcher for practical plumbing knowledge, but to make an interesting, instructive and useful reference for all interested in any branch of plumbing.

In the prepartion of these Guides, the aim of the author has been to present the subject in **the simplest possible manner,** because no matter how well informed the reader may be, he absorbs the desired information much more readily when presented in simple, brief language, than he would when confronted with an unnecessary display of technicalities.

The aim throughout has been to simplify and give information on **every phase of plumbing.**

Frank D. Graham.

OUTLINE OF CHAPTERS

READY REFERENCE INDEX
and
READERS' GUIDE

An hour with a book would have brought to your mind,
  The secret that took the whole year to find;
The facts that you learned at enormous expense,
  Were all on a library shelf to commence.

To the Reader and Student:

Read over this index occasionally and get the habit of looking for *unexpected information*. The ready reference index tells you on what pages to find the information sought for.

When you are interested and want information quickly on a problem in **Plumbing,** if you have the habit of consulting these **Plumbers' Guides** they will answer your problem.

Learn to use the index; all subjects covered are listed under their proper headings; it is also suggested to look up closely allied subjects for side lights on your problems.

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CHAPTER 102

Plumbers' Mathematics

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The plumber should have at least an elementary knowledge of mathematics and the author assumes such knowledge in presenting the subject here in condensed form, which should serve as a handy reference in looking up any mathematical process that may have been forgotten.

Signs and Abbreviations.—The various processes in mathematics to be performed are usually indicated by signs, both for convenience and brevity; for instance, 2×4 means that 2 is to be multiplied by 4.

The following table gives the numerous signs commonly used.

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Mathematical Signs

</div>

The sign $=$ means equal to, or equality;

$-$ means minus or less, or subtraction;

$+$ means plus, or addition;

$\times$ means multiplied by, or multiplication,

$\div$ or $/$ means divided by, or division;

$\left.\begin{array}{l}2\\3\end{array}\right\}$ are indexes or powers, meaning that the number to which they are added is to be squared or cubed; thus, 2^2 means two squared; 2^3, means two cubed.

$$: \text{is to}$$
$$:: \text{so is} \Bigr\} \text{ are signs of proportion;}$$
$$: \text{to}$$

$\sqrt{}$ is the radical sign and means that the square root of the number before which is placed is to be extracted;

$\sqrt[3]{}$ means that the cube root of the number before which it is placed is to be extracted;

— the bar indicates that all the numbers under it are to be taken together;

( ) the parenthesis means that all the numbers between are to be taken as one quantity;

. the decimal point means decimal parts; thus, 2.5 means $2\,^5/_{10}$, .46 means $^{46}/_{100}$.

° means degrees, ' minutes and '' seconds;

.'. means hence;

' means feet, minutes, or prime.

'' means inches, seconds, or second.

π means ratio of the circumference of a circle to its diameter, numerically 3.1416.

Abbreviations.—In addition to the signs just given certain abbreviations are used as given in the table below. The practice of some authors of writing, for instance, "*pounds per square inch*," instead of "*lbs. per sq. in.*" is not a good one because in reading it, the eye has to travel farther, resulting in fatigue and less speed in reading.*

The following abbreviations are commonly used:

Abbreviations

A or *a* = area.

A. W. G. = American Wire Gauge (Brown & Sharpe).

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*NOTE.—The same thing is true of the excessive use of capital letters. The reader will observe in these books no unnecessary capital letters are used in the text. It is a psychological fact that the omission of these capital letters results in less fatigue to the reader, though he may not be conscious of the fact.

Bbl. = barrels.

B or b = breadth.

B.h.p. = brake horse power.

B. M. = Board measure.

B.t.u. = British thermal units.

B. W. G. = Birmingham wire gauge.

B. & S. = Brown and Sharpe wire gauge (American wire gauge).

C. of g.—Center of gravity.

Cond. = Condensing.

Cu. = Cubic.

Cyl. = Cylinder.

D or d = Depth or diameter.

Deg. = Degrees.

Diam. = Diameter.

Evap. = Evaporation.

F = Coefficient of friction.

F or f = Force or factor of safety.

Ft. lbs. = Foot pounds.

Gals. = Gallons.

E or h = Height, or head of water.

H.P. = Horse power.

I. H. P. = Indicated horse power.

L, or l = length.

Lbs. = Pounds.

O. d. = Outside diameter (pipes).

Oz. = Ounces.

Pt. = Pint.

P or p = Pressure or load

Qt. = Quart.

R or r = Radius.

R.p.m. = Revolutions per minute.

□′ = Square feet.

Sq. ft. = Square foot.

Sq. in. = Square inch

□″ = Square inches.

Sq. yd. = Square yard.

T or t = Thickness, or temperature.

Temp. = Temperature.

V or v = Velocity.

Vol. = Volume.

W or w = Weight.

W. I. = Wrought iron.

Definitions

Abstract Number.—One which does not refer to any particular object.

Acute-angled Triangle.—One which has three acute angles.

Altitude (of a parallelogram or trapezoid).—The perpendicular distance between its parallel sides.

Altitude (of a prism).—The perpendicular distance between its bases.

Altitude (of a pyramid or cone).—The perpendicular distance from its vertex to the plane of its base.

Altitude (of a triangle).—A line drawn perpendicular to the base from the angle opposite.

Analysis.—The process of investigating principles, and solving problems, independently of set rules.

Angle.—The difference in direction of two lines proceeding from the same point called the vertex.

Area.—The surface included within the lines which bound a plane figure.

Arithmetic.—The science of numbers and the art of computation.

Base (of a triangle).—The side on which it may be supposed to stand.

Board Measure.—A unit for measuring lumber being a volume of a board 12 ins. wide, 1 ft. long and 1 in. thick.

Cube.—A parallelopipedon whose faces are all equal squares.

Cubic Measure.—A measure of volume involving three dimensions, length, breadth and thickness.

Circle.—A plane figure bounded by a curved line, called the circumference, every point of which is equally distant from a point within called the center.

Complex Fraction.—One whose numerator or denominator is a fraction.

Compound Fraction.—A fraction of a fraction.

Composite Numbers.—A number which can be divided by other integers besides itself and one.

Compound Numbers.—Units of two or more denominations of the same kind.

Concrete Number.—A number used to designate objects or quantities.

Cone.—A body having a circular base, and whose convex surface tapers uniformly to the vertex.

Cylinder.—A body bounded by a uniformly curved surface, its ends being equal and parallel circles.

Decimal Scale.—One in which the order of progression is uniformly ten.

Demonstration.—Process of reasoning by which a truth or principle is established.

Denomination.—Name of the unit of a concrete number.

Diagonal (*of a plane figure*).—A straight line joining the vertices of two angles not adjacent.

Diameter (*of a circle*).—A line passing through its center and terminated at both ends by the circumference.

Diameter (*of a sphere*).—A straight line passing through the center of the sphere, and terminated at both ends by its surface.

Equilateral Triangle.—One which has all its sides equal.

Even Number.—One that can be exactly divided by two.

Exact Divisor of a Number.—A whole number that will divide that number without a remainder.

Factors.—One of two or more quantities which, when multiplied together produce a given quantity.

Factors of a Number.—Numbers which, when multiplied together, make that number.

Fraction.—A number which expresses equal parts of a whole thing or quantity.

Frustum (*of a pyramid or cone*).—The part which remains after cutting off the top by a plane parallel to the base.

Geometry.—That branch of pure mathematics that treats of space and its relations.

Greatest Common Divisor.—The greatest number that will exactly divide two or more numbers.

Hypothenuse (*of a right angled triangle.*)—The side opposite the right angle.

Improper Fraction.—One whose numerator equals or exceeds its denominator.

Integer.—A number that represents whole things.

Involution.—The multiplication of a quantity by itself any number of times; raising a number to a given power.

Isosceles Triangle.—One which has two of its sides equal.

Least Common Multiple.—Least number that is exactly divisible by two or more numbers.

Like Numbers.—Same kind of unit, expressing the same kind of quantity.

Mathematics.—The science of quantity.

Measure.—That by which the extent, quantity, capacity, volume or dimensions in general is ascertained by some fixed standard.

Mensuration.—The process of measuring.

Multiple of a Number.—Any number exactly divisible by that number.

Number.—A unit or collection of units.

Obtuse-angled Triangle.—One which has one obtuse angle.

Odd Numbers.—A number which cannot be divided by two.

Parallelogram.—Quadrilateral which has its opposite sides parallel.

Parallelopipedon.—A prism bounded by six parallelograms, the opposite ones being parallel and equal.

Percentage.—Rate per hundred.

Perpendicular (of a right angled triangle).—The side which forms a right angle with the base.

Perimeter (of a polygon).—The sum of its sides.

Plane Figure.—A plane surface.

Polygon.—A plane figure bounded by straight lines.

Power.—Product arising from multiplying a number.

Prime Factor.—A prime number used as a factor.

Prime Number.—A number exactly divisible by one.

Prism.—A solid whose ends are equal and parallel polygons, and its sides parallelograms.

Problem.—A question requiring an operation.

Proper Fraction.—One whose numerator is less than its denominator.

Pyramid.—A body having for its base a polygon, and for its other faces three or more triangles, which terminate in a common point called the vertex.

Quadrilateral.—A plane figure bounded by four straight lines, and having four angles.

Quantity.—That which can be increased, diminished or measured.

Radius (of a circle).—A line extending from its center to any point in the circumference.   It is one-half the diameter.

Radius (of a sphere).—A straight line drawn from the center to any point in the surface.

Rectangle.—A parallelogram with all its angles right angles.

Rhombus.—A parallelogram whose sides are all equal, but whose angles are not right angles.

Rhomboid.—A parallelogram whose opposite sides only are equal, but whose angles are not right angles.

Right-angled Triangle.—One which has a right angle.

Root.—A factor repeated to produce a power.

Rule.—A prescribed method of performing an operation.

Scale.—Order of progression on which any system of notation is founded.

Scalene Triangle.—One which has all of its sides unequal.

Simple Fraction.—One whose numerator and denominator are whole numbers.

Simple Number.—Either an abstract number or a concrete number of but one denomination.

Slant Height (of a cone).—A straight line from the vertex to the circumference of the base.

Slant Height (of a pyramid).—The perpendicular distance from its vertex to one of the sides of the base.

Sphere.—A body bounded by a uniformly curved surface, all the points of which are equally distant from a point within called the center.

Square.—A rectangle whose sides are equal.

Trapezoid.—A quadrilateral, two of whose sides are parallel and two oblique.

Trapezium.—A quadrilateral having no two sides parallel.

Triangle.—A plane figure bounded by three sides, and having three angles.

Unit.—A single thing or a definite quantity.

Unity.—Unit of an abstract number.

Uniform Scale.—One in which the order of progression is the same throughout the entire succession of units.

Unlike Numbers.—Different kinds of units, used to express different kinds of quantity.

Varying Scale.—One in which the order of progression is not the same throughout the entire succession of units.

1. Arithmetic

Notation and Numeration.—By definition, *notation* in arithmetic is *the writing down of figures to express a number* and numeration, *the reading of the number or collection of figures already written.*

By means of the ten figures which follow any number can be expressed.

0 1 2 3 4 5 6 7 8 9 0

Numeration Table

Names of periods.	Billions.			Millions.			Thousands.			Units.				Thousandths.		
Order of Units	Hundred-billions.	Ten-billions.	Billions.	Hundred-millions.	Ten-millions.	Millions.	Hundred-thousands.	Ten-thousands.	Thousands.	Hundreds.	Tens.	Units.	Decimal point.	Tenths.	Hundredths.	Thousandths.
	7	8	6,	5	4	3,	2	0	1,	2	8	2,	.	4	8	9

This system is called Arabic notation, and is the system in ordinary every day use.

NOTE.—**Roman Notation.** This system is occasionally used as, in the Bible, for chapter headings, corner stones, etc. The method of expressing numbers is by letters, thus:

Roman Table

I denotes One	XII denotes Twelve	L denotes Fifty
II denotes Two	XIII denotes Thirteen	LX denotes Sixty
III denotes Three	XIV denotes Fourteen	LXX denotes Seventy
IV denotes Four	XV denotes Fifteen	LXXX denotes Eighty
V denotes Five	XVI denotes Sixteen	XC denotes Ninety
VI denotes Six	XVII denotes Seventeen	C denotes One hundred
VII denotes Seven	XVIII denotes Eighteen	D denotes Five hundred
VIII denotes Eight	XIX denotes Nineteen	$\overline{\text{M}}$ denotes One thousand
IX denotes Nine	XX denotes Twenty	$\overline{\text{X}}$ denotes Ten thousand
X denotes Ten	XXX denotes Thirty	M denotes One million
XI denotes Eleven	XL denotes Forty	

The following 10 formulæ include the elementary operations of arithmetic.

1. *The sum = all the parts added.*
2. *The difference = the minuend — the subtrahend.*
3. *The minuend = the subtrahend + the difference.*
4. *The subtrahend = the minuend — the difference.*
5. *The product = the multiplicand × the multiplier.*
6. *The multiplicand = the product ÷ the multiplier.*
7. *The multiplier = the product ÷ the multiplicand.*
8. *The quotient = the dividend ÷ the divisor.*
9. *The dividend = the quotient × the divisor.*
10. *The divisor = the dividend ÷ the quotient.*

Addition.—The sign of addition is+and is read "plus", thus 7+3 is read "seven plus three."

Rule A.—*Write the numbers to be added so that like orders of units stand in the same column.*

B.—*Commencing with the lowest order, or at the right hand, add each column separately, and if the sum can be expressed by one figure, write it under the column added.*

C.—*If the sum of any column contain more than one figure, write the unit figure under the column added, and add the remaining figure or figures to the next column.*

NOTE.—*Continued.*

In the Roman notation, when any character is placed at the right hand of a larger numeral, its value is added to that of such numeral; as, VI, that is, V+I; XV, that is, X+V; MD, that is, M+D; and the like. I, X, and rarely C, are also placed at the left hand of other and larger numerals, and when so situated their value is subtracted; as, IV, that is, V—I; XC, that is, C—X; and the like. Formerly the smaller figure was sometimes repeated in such a position twice, its value being in such cases subtracted from the larger; as, IIX, that is, X—II XXC, that is, C—XX; and the like. Sometimes after the sign IƆ for D, the character Ɔ was repeated one or more times, each repetition having the effect to multiply IƆ by ten; as, IƆƆ, 5,000; IƆƆƆ, 50,000; and the like. To represent numbers twice as great as these, C was repeated as many times before the stroke I, as the Ɔ was after it: as, CCIƆƆƆ, 10,000; CCCIƆƆƆ, 100,000; and the like. *The ridiculous custom* of using the Roman notation for chapter numbers, year of copyright, sections, etc., should be discontinued.

Examples for Practice

7,060	248,124	13,579,802
9,420	4,321	93
1,743	889,866	478,652
4,004	457,902	87,547,289

22,227 Ans.

Use great care in placing the numbers in vertical lines, as irregularity in writing them down is one cause of mistakes.

Subtraction.—The sign of subtraction is − and is read "minus," thus $10 - 7$ is read "ten minus seven" or "seven from ten "

Rule—A.—*Write down the sum so that the units stand under the units, the tens under the tens, etc., etc.*

B.—*Begin with the units, and take the under from the upper figure, and put the remainder beneath the line.*

C.—*If the lower figure be the larger, add ten to the upper figure, and then subtract and put the remainder down; this borrowed ten must be deducted from the next column of figures* where it is represented by 1.

Examples for Practice

892	2,572	9,999
46	1,586	8,971

846 remainder.

Multiplication.—The sign of multiplication is $\times$ and is read "times" or multiplied by; thus 6×8 is read, 6 times 8 is 48, or, 6 multiplied by 8 is 48.

The principle of multiplication is the same as addition, thus $3 \times 8 = 24$ is the same as $8 + 8 + 8 = 24$.

Rule.—*Place the unit figure of the multiplier under the unit figure of the multiplicand and proceed as in the following examples*:

Example.—Multiply 846 by 8; and 478,692 by 143.   Arrange them thus:

```
     846                487,692
       8                    143
  ------                -------
   6,768                1463076
                        1950768
                        487692
                       --------
                      69,739,956
```

Rule.—*If the multiplier have ciphers at its end, place it as in the following examples*:

Example.—Multiply 83567 by 50; and 898 by 2800.

```
                                    898
                                   2800
                                 -------
       83567                      718400
          50                      1796
     -------                    ---------
   4,178,350                    2,514,400
```

Division.—The sign of division is $\div$ and is read "divided by," thus $8 \div 2$ is read "eight divided by two."

There are two methods of division known as: 1, short division, and 2, long division.

1. *Short division.*

To divide by any number up to 12.

Rule.—*Put the dividend down with the divisor to the left of it, with a small curved line separating it, as in the following*:

Example.—Divide 7,865,432 by 6.

$$6)\overline{7,865,432}$$
$$1,310,905 - 2$$

Here at the last we have to say 6 into 32 goes 5 times and 2 over; always place the number that is over as above, as a fraction, thus $^2/_6$ the top figure being the remainder and the bottom figure the divisor, when it should be put close to the quotient; thus $1,310,905 \, ^2/_6$.

To divide by any number up to 12 with a cipher or ciphers after it as 20, 70, 500, 7,000, etc.

Rule.—*Place the sum down as in the last example, then mark off from the right of the dividend as many figures as there are ciphers in the divisor; also mark off the ciphers in the divisor; then divide the remaining figures by the number remaining in the divisor, thus*:

Example.—Divide 9,876,804 by 40.

$$40)\overline{9,876,804}$$
$$246,920 \, ^4/_{40}$$

2. *Long division.*

To divide any number by a large divisor of two or more figures.

Example.—Divide 18,149 by 56.

$$56)18149(324 \, ^5/_{56}$$
$$\underline{168}$$
$$\overline{134}$$
$$\underline{112}$$
$$\overline{229}$$
$$\underline{224}$$
$$\overline{5}$$

In the above operation the process is as follows: As neither 1 nor 18 will contain the divisor, take three figures 181, for the first *partial* dividend. 56 is contained in 181 three times, and a remainder. Write the 3, as the first figure in the quotient, and then multiply the divisor by this quotient figure thus: 3 times 56 is 168, which when subtracted from 181 leaves 13. To this remainder annex or "bring down" 4 the next figure in the dividend thus forming 134, which is the next partial dividend. 56 is contained in 134 two times and a remainder. Thus 2 times 56 is 112, which subtracted from 134 leaves 22. To the remainder bring down 9 the last figure in the dividend, forming 229, the last partial dividend. 56 is contained in 229 four times and a remainder. Thus: $4 \times 56 = 224$, which, subtracted from 229, gives 5, the final remainder which write in the quotient with the division below it, thus completing the operation of long division.

Factors.—4 and 5 are factors of 20 because 4 multiplied by 5 equals 20.

Rule.—*Divide the given number by any prime factor; divide the quotient in the same manner, and so continue the division until the quotient is a prime number. The several divisors and the last quotient will be the prime factors required.*

Example.—What are the prime factors of 798

$$
\begin{array}{r|l}
2 & 798 \\
3 & 399 \\
7 & 133 \\
19 & 19 \\
\hline
 & 1
\end{array}
$$

Greatest Common Divisor.—5 is the greatest common divisor of 10 and 15 because it is the greatest number that will exactly divide each of them.

Rule.—1. *Write the numbers in a line, with a vertical line at the left, and divide by any factor common to all the numbers.* 2. *Divide the quotient in like manner, and continue the dividend till*

a set of quotients is obtained that are prime to each other.   **3.** *Multiply all the divisors together and the product will be the greatest common divisor sought.*

Example.—What is the greatest common divisor of 72, 120 and 440?

$$
\begin{array}{r|rrr}
4 & 72 & 120 & 440 \\
\hline
2 & 18 & 30 & 110 \\
\hline
& 9 & 15 & 55
\end{array}
$$

Least Common Multiple.—6 is the least common multiple of 2 and 3 because it is the least number exactly divisible by those numbers.

Rule.—**1.** *Resolve the given numbers into their prime factors.* **2.** *Multiply together all the prime factors of the largest number, and such prime factors of the other numbers as are not found in the largest number. Their product will be the least common multiple.* **3.** *When a prime factor is repeated in any of the given numbers it must be taken as many times in the multiple, as the greatest number of times it appears in any of the given numbers.*

Example.—Find the least common multiple of 60, 84 and 132.

$$60 = 2 \times 2 \times 3 \times 5$$
$$84 = 2 \times 2 \times 3 \times 7$$
$$132 = 2 \times 2 \times 3 \times 11$$
$$(2 \times 2 \times 3 \times 11) \times 5 \times 7 = 4,620$$

Fractions.—If a unit or whole number be divided into 2 equal parts, one of these parts is called one-half, written $\frac{1}{2}$.

1. To reduce a common fraction to its lowest terms,

Rule.—Divide both terms by their greatest common divisor.

Thus: $^9/_{15} = \dfrac{3}{5}$

2. To change an improper fraction to a mixed number,

Rule.—*Divide the numerator by the denominator; the quotient is the whole number and the remainder placed over the denominator is the fraction.*

$$\text{Thus: } \frac{23}{4} = 5\,\tfrac{3}{4}$$
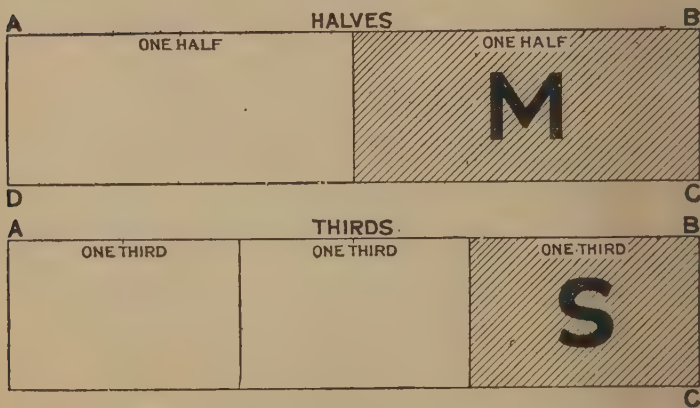
Figs. 5,838 and 5,839.—Graphic representation of fractional parts. The figures show a rectangle ABCD, representing a unit divided into two equal parts or halves (fig. 5,838) and into three equal parts or thirds (fig. 5,839). Evidently the shaded section **M**, or one half is larger than the shaded section **S**, or one third.

3. To change a mixed number to an improper fraction,

Rule.—*Multiply the whole number by the denominator of the fraction; to the product add the numerator; place the sum over the denominator.* Thus $1\tfrac{3}{8} = {}^{11}/_{8}$.

4. To reduce a compound to a simple fraction, also to multiply fractions,

Rule.—*Multiply the numerators together for a new numerator and the denominators together for a new denominator.*

$$\text{Thus: } \frac{1}{2} \text{ of } \frac{2}{3} = \frac{2}{6} \text{ also } \frac{1}{2} \times \frac{2}{3} = \frac{2}{6}$$

5. To reduce a complex to a simple fraction,

Rule.—*The numerator and denominator must each first be given the form of a simple fraction; then multiply the numerator of the upper fraction by the denominator of the lower for the new numerator, and the denominator of the upper by the numerator of the lower for the new denominator.*

$$\text{Thus: } \frac{\frac{7}{8}}{1\frac{3}{4}} = \frac{\frac{7}{8}}{\frac{7}{4}} = \frac{28}{56} = \frac{1}{2}$$

6. To add fractions,

Rule.—*Reduce them to a common denominator, add the numerators and place their sum over the common denominator.*

$$\text{Thus: } \frac{1}{2} + \frac{1}{4} = \frac{4+2}{8} = \frac{6}{8} = \frac{3}{4}$$

7. To subtract fractions,

Rule.—*Reduce them to a common denominator, subtract the numerators and place the difference over the common denominator.*

$$\text{Thus: } \frac{1}{2} - \frac{1}{4} = \frac{4-2}{8} = \frac{2}{8} = \frac{1}{4}$$

8. To multiply fractions,

Rule I.—(Multiplying by a whole number)—*Multiply the numerator or divide the denominator by the whole number.*

$$\text{Thus: } \tfrac{1}{2} \times 3 = {}^{3}/_{2} = 1\tfrac{1}{2}$$

9. To divide fractions,

Rule I.—(Dividing by a whole number)—*Divide the numerator, or multiply the denominator by the whole number.*

$$\text{Thus: dividing, } \frac{10}{13} \div 5 = \frac{2}{13}; \text{ multiplying } \frac{10}{13} \div 5 = \frac{10}{65} = \frac{2}{13}$$

Rule II.—(Dividing by a fraction)—*Invert the divisor and proceed as in multiplication.*

$$\text{Thus: } \tfrac{3}{4} \div \frac{5}{7} = \frac{3}{4} \times \frac{7}{5} = \frac{21}{20} = 1\tfrac{1}{20}$$

Decimal Fractions.—Any decimal or combination of a decimal and integer may be read by applying the table on next page.

The important thing about decimals is to *always plainly put down the decimal point.* And in case of a column of figures as in addition, care should be taken to have all the decimal points exactly under each other.

1. To reduce a decimal to a common fraction,

Rule.—*Write down the denominator and reduce the common fraction thus obtained to its lowest terms.*

$$\text{Thus: } .25 = \frac{25}{100} = \frac{1}{4}$$

Numeration of Decimals

Hundred thousandths	Thousandths	Hundredths	Tens	Units	Decimal point	Tens	Hundredths	Thousandths	Tens of Thousandths	Hundred thousandths
1	**2**	**3**	**4**	**5**	**·**	**1**	**2**	**3**	**4**	**5**
5th order	4th order	3rd order	2nd order	1st order		1st order	2nd order	3rd order	4th order	5th order

Integers   *Decimals*

2. To add and subtract decimals,

Rule.—(*Addition*)—*Place the numbers in a column with the decimal points under each other and add as in whole numbers.*

Rule.—(*Subtraction*)—*Place the numbers so that the decimal points are under each other and proceed as in simple subtraction.*

Examples.—

Addition	Subtraction
.5	1.25
.25	.75
1.75	———
———	.50
2.50	

3. To multiply decimals,

Rule.—*Proceed as in simple multiplication and point off as many places as there are in multiplier and multiplicand.*

Thus: .1 × .0025 = .00025

4. To divide decimals,

Rule.—*Proceed as in simple division, and from the right hand of the quotient point off as many places for decimals as the decimal places in the dividend exceed those in the divisor.*

Thus: 1.5 ÷ .25 = 6

FIRST ORDER OR "TENTHS" (.1)

SECOND ORDER OR "HUNDREDTHS" (.01)

THIRD ORDER OR "THOUSANDTHS" (.001)

FIGS. 5,840 to 5,842.—Graphic representation of decimal fractions. Fig. 5,840, a unit divided into ten parts—1st order of "tens"; fig. 5,841, one of the "tens" as LARF, divided into ten parts—2nd order or "hundredths"; fig. 5,942, one of the "hundredths" as *larf*, divided into ten parts—3rd order or thousandths. Similarly the process of division may be continued indefinitely.

5. To reduce common fractions to decimals.

Fractional Inch Decimal Equivalent

8ths	32ds	64ths
1/8 = .125		1/64 = .015625
1/4 = .250		3/64 = .046875
3/8 = .375		5/64 = .078125
1/2 = .500		7/64 = .109375
5/8 = .625		9/64 = .140625
3/4 = .750		11/64 = .171875
7/8 = .875		13/64 = .203125
	1/32 = .03125	15/64 = .234375
	3/32 = .09375	17/64 = .265625
	5/32 = .15625	19/64 = .296875
	7/32 = .21875	21/64 = .328125
	9/32 = .28125	23/64 = .359375
	11/32 = .34375	25/64 = .390625
	13/32 = .40625	27/64 = .421875
	15/32 = .46875	29/64 = .453125
	17/32 = .53125	31/64 = .484375
	19/32 = .59375	33/64 = .515625
	21/32 = .65625	35/64 = .546875
	23/32 = .71875	37/64 = .578125
	25/32 = .78125	39/64 = .609375
	27/32 = .84375	41/64 = .640625
	29/32 = .90625	43/64 = .671875
16ths	31/32 = .96875	45/64 = .703125
1/16 = .0625		47/64 = .734375
3/16 = .1875		49/64 = .765625
5/16 = .3125		51/64 = .796875
7/16 = .4375		53/64 = .828125
9/16 = .5625		55/64 = .859375
11/16 = .6875		57/64 = .890625
13/16 = .8125		59/64 = .921875
15/16 = .9375		61/64 = .953125
		63/64 = .984375

Rule.—*Divide the numerator by the denominator and carry out the division to as many decimal places as desired.*

$$\text{Thus: } \frac{4}{5} = 4 \div 5 = .8$$

Fractional Inch Decimal Equivalents.—The tables of decimal equivalents of common fractions given on the preceding page will be found very useful.

Fractional Foot Decimal Equivalents.—The following table of decimals of a foot equivalent to inches and fractions of an inch will be found useful especially in mensuration calculations.

Decimals of a Foot and Inches

Inch	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	.0	.0833	.1677	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
1-16	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
1-8	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
3-16	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
1-4	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
5-16	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
3-8	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
7-16	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
1-2	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
9-16	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
5-8	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
11-16	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
3-4	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792
13-16	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
7-8	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
15-16	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948

Ratio and Proportion.—A ratio is virtually a fraction. When two ratios are equal the four terms form a proportion. Thus $2:4::3:6$, which is read: As 2 is to 4 so is 3 to 6. Sometimes the sign $=$ is placed between the two ratios instead of the sign $::$, thus $2:4=3:6$.

Rule I.—*Two quantities of **different** kinds cannot form the terms of a ratio.*

Rule II.—*The product of the extremes equals the product of the means.*

Thus $4 : 8 = 2 : 4$; applying Rule II, $4 \times 4 = 8 \times 2$ or $16 = 16$.

"Rule of Three."—When three terms of a proportion are given, the method of finding the fourth term is called the "*rule of three*."

Example.—If five bundles of shingles cost $16, what will 25 bundles cost? Letting X equal the unknown term then 5 bundles : 25 bundles = $16 : $X.

$$5 \times X = 25 \times 16; \quad X = \frac{25 \times 16}{5} = \$80$$

Percentage.—A profit of 6% means a gain of $6 on every $100.

Note carefully with respect to the symbol $\%$. 5% means $^5/_{100}$ which when reduced to a decimal (as is necessary in making a calculation) becomes .05, but $.05\%$ has a quite different value, thus

$.05\%$ means $.^{05}/_{100}$ which when reduced to a decimal becomes .0005, that is, $^5/_{100}$ of 1%.

Rule.—*If the decimal have more than two places, the figures that follow the hundredths place signify parts of 1%.*

Example.—If the list price of Perfection shingles be $16 per 1,000, what is the net cost with 5% discount for cash?

$$5\% = \frac{5}{100} = .05; \quad 16 \times .05 = 80c; \quad \$16 - .80c = \$15.20$$

Powers of Numbers.—The "square" of a number is its second power; the "cube," its third power. Thus: square of

$$2 = 2 \times 2 = 4; \text{ cube of } 2 = 2 \times 2 \times 2 = 8.$$

The power to which a number is raised is indicated by a

Squares, Cubes, Square Roots and Cube Roots

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1	1	1	1.00000	1.00000	1.00000
2	4	8	1.41421	1.25992	.50000
3	9	27	1.73205	1.44224	.33333
4	16	64	2.00000	1.58740	.25000
5	25	125	2.23606	1.70997	.20000
6	36	216	2.44948	1.81712	.16666
7	49	343	2.64575	1.91293	.14285
8	64	512	2.82842	2.00000	.12500
9	81	729	3.00000	2.08008	.11111
10	100	1000	3.16227	2.15443	.10000
11	121	1331	3.31662	2.22398	.09090
12	144	1728	3.46410	2.28942	.08333
13	169	2197	3.60555	2.35133	.07692
14	196	2744	3.74165	2.41014	.07142
15	225	3375	3.87298	2.46621	.06666
16	256	4096	4.00000	2.51984	.06250
17	289	4913	4.12310	2.57128	.05882
18	324	5832	4.24264	2.62074	.05555
19	361	6859	4.35889	2.66840	.05263
20	400	8000	4.47213	2.71441	.05000
21	441	9621	4.58257	2.75892	.04761
22	484	10648	4.69041	2.80203	.04545
23	529	12167	4.79583	2.84386	.04347
24	576	13824	4.89897	2.88449	.04166
25	625	15625	5.00000	2.92401	.04000
26	676	17576	5.09901	2.96249	.03846
27	729	19683	5.19615	3.00000	.03703
28	784	21952	5.29150	3.03658	.03571
29	841	24389	5.38516	3.07231	.03448
30	900	27000	5.47722	3.10723	.03333
31	961	29791	5.56776	3.14138	.03225
32	1024	32768	5.66685	3.17480	.03125
33	1089	35937	5.74456	3.20753	.03030
34	1156	39304	5.83095	3.23961	.02941
35	1225	42875	5.91607	3.27106	.02857
36	1296	46656	6.00000	3.30192	.02777
37	1369	50653	6.08276	3.33222	.02702
38	1444	54872	6.16441	3.36197	.02631
39	1521	59319	6.24499	3.39121	.02564
40	1600	64000	6.32455	3.41995	.02500
41	1681	68921	6.40312	3.44821	.02439
42	1764	74088	6.48074	3.47602	.02380
43	1849	79507	6.55743	3.50339	.02325
44	1936	85184	6.63324	3.53034	.02272
45	2025	91125	6.70820	3.55689	.02222
46	2116	97336	6.78233	3.58304	.02173
47	2209	103823	6.85565	3.60882	.02127
48	2304	110592	6.92820	3.63424	.02083
49	2401	117649	7.00000	3.65930	.02040
50	2500	125000	7.07106	3.68403	.02000
51	2601	132651	7.14142	3.70842	.01960
52	2704	140608	7.21110	3.73251	.01923
53	2809	148877	7.28010	3.75628	.01886
54	2916	157464	7.34846	3.77976	.01851
55	3025	166375	7.41619	3.80295	.01818
56	3136	175616	7.48331	3.82586	.01785
57	3249	185193	7.54983	3.84850	.0 764
58	3364	195112	7.61577	3.87087	.01724

small "superior" figure called an "exponent." Thus: $2^2 = 2 \times 2 = 4$; $2^3 = 2 \times 2 \times 2 = 8$.

Roots of Numbers (Evolution).—In the equation $2 \times 2 = 4$, 2 is the root for which the power (4) is produced. The radical sign $\sqrt{}$ placed over a number means the root of the number is to be extracted, thus $\sqrt{4}$ means that the square root of 4 is to be extracted. The *index* of the root is a small figure placed over the radical.

Squares, Cubes and Roots—*Continued.*

No.	Square	Cube	Square Root	Cube Root	Reciprocal
59	3481	205379	7.68114	3.89299	.01694
60	3600	216000	7.74596	3.91486	.01666
61	3721	226981	7.81024	3.93649	.01639
62	3844	238328	7.87400	3.95789	.01612
63	3969	250047	7.93725	3.97905	.01587
64	4096	262144	8.00000	4.00000	.01562
65	4225	274625	8.06225	4.02072	.01538
66	4356	287496	8.12403	4.04124	.01515
67	4489	300763	8.18535	4.06154	.01492
68	4624	314432	8.24621	4.08165	.01470
69	4761	328509	8.30662	4.10156	.01449
70	4900	343000	8.36660	4.12128	.01428
71	5041	357911	8.42614	4.14081	.01408
72	5184	373248	8.48528	4.16016	.01388
73	5329	389017	8.54400	4.17933	.01369
74	5476	405224	8.60232	4.19833	.01351
75	5625	421875	8.66025	4.21716	.01333
76	5776	438976	8.71779	4.23582	.01315
77	5929	456533	8.77496	4.25432	.01298
78	6084	474552	8.83176	4.27265	.01282
79	6241	493039	8.88819	4.29084	.01265
80	6400	512000	8.94427	4.30886	.01250
81	6561	531441	9.00000	4.32674	.01234
82	6724	551368	9.05538	4.34448	.01219
83	6889	571787	9.11043	4.36207	.01204
84	7056	592704	9.16515	4.37951	.01190
85	7225	614125	9.21954	4.39682	.01176
86	7396	636056	9.27361	4.41400	.01162
87	7569	658503	9.32737	4.43104	.01149
88	7744	681472	9.38083	4.44796	.01136
89	7921	704969	9.43398	4.46474	.01123
90	8100	729000	9.48683	4.48140	.01111
91	8281	753571	9.53939	4.49794	.01098
92	8464	778688	9.59166	4.51435	.01086
93	8649	804357	9.64365	4.53065	.01075
94	8836	830584	9.69535	4.54683	.01063
95	9025	857375	9.74679	4.56290	.01052
96	9216	884736	9.79795	4.57885	.01041
97	9409	912673	9.84885	4.59470	.01030
98	9604	941192	9.89949	4.61043	.01020
99	9801	970299	9.94987	4.62606	.01010
100	10000	1000000	10.00000	4.64158	.01000

Rule.—(Square Root)—Point off the given number into periods of two places each, beginning with units. If there be decimals, point these off likewise, beginning at the decimal point. and supplying as many ciphers as may be needed. Find the greatest number whose square is less than the first left hand period, and place it as the first figure in the quotient. Subtract its square from the left hand period, and to the remainder annex the two figures of the second period for a dividend. Double the first figure of the quotient for a partial divisor; find how many times the latter is contained in the dividend exclusive of the right hand figure, in the quotient, and annex it to the right of the partial divisor, forming the complete divisor. Multiply this divisor by the second figure in the quotient, and subtract the product from the dividend. To the remainder bring down the next period and proceed as before, in each case doubling the figures in the root already found to obtain the trial divisor. Should the product of the second figure in the root by the completed divisor be greater than the dividend, erase the second figure both from the quotient and from the divisor, and substitute the next smaller figure, or one small enough to make the product of the second figure by the divisor less than or equal to the dividend.

Rule.—(Roots higher than the cube)—The fourth root is the square root of the square root; the sixth root is the cube root of the square root or the square root of the cube root. Other roots are most conveniently found by the use of logarithms.

Rule.—(*Cube*) *root*. **1.** *Separate the number into groups of three figures each, beginning at the units.* **2.** *Find the greatest cube in the left hand group and write its root for the first figure of the required root.* **3.** *Cube this root, subtract the result from the*

left hand group, and to the remainder annex the next group for a dividend. 4. For a partial divisor, take three times the square of the root already found, considered as tens, and divide the dividend by it. The quotient (or the quotient diminished) will be the second figure of the root. 5. To this partial divisor add three times the product of the first figure of the root considered as tens by the second figure, and also the square of the second figure. This sum will be the complete divisor. 6. Multiply the complete divisor by the second figure of the root, subtract the product from the dividend, and to the remainder annex the next group for a new dividend. 7. Proceed in this manner until all the groups have been annexed. The result will be the cube root required.

SQUARE ROOT.

$$\overset{}{3}.\overset{}{1}\overset{}{4}1\overset{}{5}9\overset{}{2}6\overset{}{5}36\underline{|1.77245\,+}$$

1

27	$\underline{2}\overline{14}$
	$\underline{189}$
347	2515
	$\underline{2429}$
3542	8692
	$\underline{7084}$
35444	160865
	$\underline{141776}$
354485	1908936
	$\underline{1772425}$

CUBE ROOT.

$$\overset{.}{1},8\overset{.}{8}1,36\overset{.}{5},96\overset{.}{3},62\overset{.}{5}\underline{|12345}$$

1

$$\begin{array}{rl} 300\times 1^2 & = 300 \\ 30\times 1\ \times 2 & = 60 \\ 2^2 & = \underline{4} \\ 364 \end{array}\ \bigg|\ \begin{array}{l}881 \\ 728 \end{array}$$

$$\begin{array}{rl} 300\times 12^2 & = 43200 \\ 30\times 12\ \times 3 & = 1080 \\ 3^2 & = \underline{9} \\ 44289 \end{array}\ \bigg|\ \begin{array}{l}153365 \\ 132867 \end{array}$$

$$\begin{array}{rl} 300\times 123^2 & = 4538700 \\ 30\times 123\ \times 4 & = 14760 \\ 4^2 & = \underline{16} \\ 4553476 \end{array}\ \bigg|\ \begin{array}{l}20498963 \\ 18213904 \end{array}$$

$$\begin{array}{rl} 300\times 1234^2 & = 456826800 \\ 30\times 1234\times 5 & = 185100 \\ 5^2 & = \underline{25} \\ 457011925 \end{array}\ \bigg|\ \begin{array}{l}2285059625 \\ .2285059625 \end{array}$$

The Metric System.—*The important feature of the metric system is that it is based upon the* **decimal scale,** *hence, the student should first acquire a knowledge of decimals before taking up this system.*

The *meter* is the base or unit of the system and is defined as the one ten-millionth part of the distances on the earth's surface from the equator to either pole. Its value in inches should be remembered.

1 meter = 39.37079 ins.

In this system, weights and measures are increased or decreased by the following words prefixed to them:

Millimeter into Inches

mm.	inches	mm.	inches	mm.	inches
1/50 =	.00079	26/50 =	.02047	2 =	.07874
2/50 =	.00157	27/50 =	.02126	3 =	.11811
3/50 =	.00236	28/50 =	.02205	4 =	.15748
4/50 =	.00315	29/50 =	.02283	5 =	.19685
5/50 =	.00394	30/50 =	.02362	6 =	.23622
6/50 =	.00472	31/50 =	.02441	7 =	.27559
7/50 =	.00551	32/50 =	.02520	8 =	.31496
8/50 =	.00630	33/50 =	.02598	9 =	.35433
9/50 =	.00709	34/50 =	.02677	10 =	.39370
10/50 =	.00787	35/50 =	.02756	11 =	.43307
11/50 =	.00866	36/50 =	.02835	12 =	.47244
12/50 =	.00945	37/50 =	.02913	13 =	.51181
13/50 =	.01024	38/50 =	.02992	14 =	.55118
14/50 =	.01102	39/50 =	.03071	15 =	.59055
15/50 =	.01181	40/50 =	.03150	16 =	.62992
16/50 =	.01260	41/50 =	.03228	17 =	.66929
17/50 =	.01339	42/50 =	.03307	18 =	.70866
18/50 =	.01417	43/50 =	.03386	19 =	.74803
19/50 =	.01496	44/50 =	.03465	20 =	.78740
20/50 =	.01575	45/50 =	.03543	21 =	.82677
21/50 =	.01654	46/50 =	.03622	22 =	.86614
22/50 =	.01732	47/50 =	.03701	23 =	.90551
23/50 =	.01811	48/50 =	.03780	24 =	.94488
24/50 =	.01890	49/50 =	.03858	25 =	.98425
25/50 =	.01969	1 =	.03937	26 =	1.02362

Inches into Millimeters

In.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16
0	0.0	1.6	3.2	4.8	6.4	7.9	9.5	11.1
1	25.4	27.0	28.6	30.2	31.7	33.3	34.9	36.5
2	50.8	52.4	54.0	55.6	57.1	58.7	60.3	61.9
3	76.2	77.8	79.4	81.0	82.5	84.1	85.7	87.3
4	101.6	103.2	104.8	106.4	108.0	109.5	111.1	112.7
5	127.0	128.6	130.2	131.8	133.4	134.9	136.5	138.1
6	152.4	154.0	155.6	157.2	158.8	160.3	161.9	163.5
7	177.8	179.4	181.0	182.6	184.2	185.7	187.3	188.9
8	203.2	204.8	206.4	208.0	209.6	211.1	212.7	214.3
9	228.6	230.2	231.8	233.4	235.0	236.5	238.1	239.7
10	254.0	255.6	257.2	258.8	260.4	261.9	263.5	265.1
11	279.4	281.0	282.6	284.2	285.7	287.3	288.9	290.5
12	304.8	306.4	308.0	309.6	311.1	312.7	314.3	315.9
13	330.2	331.8	333.4	335.0	336.5	338.1	339.7	341.3
14	355.6	357.2	358.8	360.4	361.9	363.5	365.1	366.7
15	381.0	382.6	384.2	385.8	387.3	388.9	390.5	392.1
16	406.4	408.0	409.6	411.2	412.7	414.3	415.9	417.5
17	431.8	433.4	435.0	436.6	438.1	439.7	441.3	442.9
18	457.2	458.8	460.4	462.0	463.5	465.1	466.7	468.3
19	482.6	484.2	485.8	487.4	488.9	490.5	492.1	493.7
20	508.0	509.6	511.2	512.8	514.3	515.9	517.5	519.1
21	533.4	535.0	536.6	538.2	539.7	541.3	542.9	544.5
22	558.8	560.4	562.0	563.6	565.1	566.7	568.3	569.9
23	584.2	585.8	587.4	589.0	590.5	592.1	593.7	595.3

In.	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0	12.7	14.3	15.9	17.5	19.1	20.6	22.2	23.8
1	38.1	39.7	41.3	42.9	44.4	46.0	47.6	49.2
2	63.5	65.1	66.7	68.3	69.8	71.4	73.0	74.6
3	88.9	90.5	92.1	93.7	95.2	96.8	98.4	100.0
4	114.3	115.9	117.5	119.1	120.7	122.2	123.8	125.4
5	139.7	141.3	142.9	144.5	146.1	147.6	149.2	150.8
6	165.1	166.7	168.3	169.9	171.5	173.0	174.6	176.2
7	190.5	192.1	193.7	195.3	196.9	198.4	200.0	201.6
8	215.9	217.5	219.1	220.7	222.3	223.8	225.4	227.0
9	241.3	242.9	244.5	246.1	247.7	249.2	250.8	252.4
10	266.7	268.3	269.9	271.5	273.1	274.6	276.2	277.8
11	292.1	293.7	295.3	296.9	298.4	300.0	301.6	303.2
12	317.5	319.1	320.7	322.3	323.8	325.4	327.0	328.6
13	342.9	344.5	346.1	347.7	349.2	350.8	352.4	354.0
14	368.3	369.9	371.5	373.1	374.6	376.2	377.8	379.4
15	393.7	395.3	396.9	398.5	400.0	401.6	403.2	404.8
16	419.1	420.7	422.3	423.9	425.4	427.0	428.6	430.2
17	444.5	446.1	447.7	449.3	450.8	452.4	454.0	455.6
18	469.9	471.5	473.1	474.7	476.2	477.8	479.4	481.0
19	495.3	496.9	498.5	500.1	501.6	503.2	504.8	506.4
20	520.7	522.3	523.9	525.5	527.0	528.6	530.2	531.8
21	546.1	547.7	549.3	550.9	552.4	554.0	555.6	557.2
22	571.5	573.1	574.7	576.3	577.8	579.4	581.0	582.6
23	596.9	598.5	600.1	601.7	603.2	604.8	606.4	608.0

Milli expresses the 1,000th part.
Centi   "   "   100th   "
Deci   "   "   10th   "
Deka   "   10 times the value
Hecto   "   100   "   "   "
Kilo   "   1,000   "   "   "

Table

1 Millimeter....(¹/₁₀₀₀ of a meter)	=	.03937	*in.*
10 *mm.* = 1 Centimeter....(¹/₁₀₀ of a meter)	=	.3937	*in.*
10 *cm.* = 1 Decimeter ..(¹/₁₀ of a meter)	=	3.937	*in.*
10 *dm.* = 1 Meter........(1 meter)	=	39.37	*in.*
10 *m.* = 1 Dekameter....(10 meters)	=	32.8	*ft.*
10 *Dm.* = 1 Hectometer ..(100 meters)	=	328.09	*ft.*
10 *Hm* = 1 Kilometer.....(1000 meters)	=	.62137	*mile.*

Metric Equivalent

TABLE   SQUARE MEASURE

1 sq. centimeter = 0.1550 sq. in.	1 sq. in. = 6.452 sq. centimeters
1 sq. decimeter = 0.1076 sq. ft.	1 sq. ft = 9.2903 sq. decimeters.
1 sq. meter = 1.196 sq. yd.	1 sq. yd. = 0.8361 sq. m'r.
1 are. = 3.954 sq. rd.	1 sq. rd = 0.2529 are.
1 hektar = 2.47 acres.	1 acre = 0.4047 hektar.
1 sq kilometer = 0.386 sq. mile.	1 sq mile = 2.59 sq. kilometers.

TABLE   WEIGHTS

1 gram = 0.0527 ounce.	1 ounce = 28.35 grams.
1 kilogram = 2.2046 lbs.	1 lb = 0.4536 kilogram.
1 metric ton = 1.1023 English ton.	1 English ton = 0.9072 metric ton.

TABLE   APPROXIMATE METRIC EQUIVALENTS

1 decimeter = 4 inches.	1 liter = 1.06 qt. liquid 0.9 qt. dry.
1 meter = 1.1 yards.	1 hektoliter = 2⅚ bus.
1 kilometer = ⅝ of a mile.	1 kilogram = 2 1/5 lbs.
1 hektar = 2½ acres.	1 metric ton = 2,200 lbs.
1 stere. or cu. meter = ¼ of a cord.	

NOTE.—A gramme is the weight of a cubic centimeter of distilled water; a decigramme contains ¹/₁₀ of a gramme; a dekagramme contains 10 grammes.

Measures.—There are several kinds of measure, as:

1. Linear (length).
2. Square (area).
3. Cubic (volume).
4. Weight
5. Time.
6. Angular, etc.

The following tables give the various measures in common use:

Long Measure

12 inches (ins. or ″)	make 1 foot (ft. or ′)
3 feet	make 1 yard (yd.)
5½ yards or 16½ feet	make 1 rod (rd.)
40 rods	make 1 furlong (fur.)
8 furlongs or 320 rods	make 1 statute mile (mi.)

Unit equivalents

				ft.		ins.
			yd.	1	=	12
		rd.	1 =	3	=	36
fur.	1 =	5½ =	16½ =	198
mi. 1=	40 =	220 =	660 =	7,920
1 = 8 =	320 =	1,760 =	5,280 =	63,360

Scale—ascending, 12, 3, 5½, 40, 8; descending, 8, 40, 5 ½, 3, 12.

Nautical Measure

6,080.26 ft. or 1.15156 statute miles = 1 nautical mile or knot*
3 nautical miles = 1 league
60 nautical miles or 69.168 statute miles = 1 degree (at the equator)
360 degrees = circumference of earth at equator

Square Measure

144 square inches (sq. ins.) make 1 square foot (sq. ft.)
9 sq. ft. make 1 square yard (sq. yd.)
30¼ sq. yds. make 1 square rod or perch (sq. rd. or P.)
40 rods make 1 rood (R)
4 roods make 1 acre (A)
640 acres make 1 square mile (sq. mi.)

Unit equivalents

					sq. ft.		sq. ins.
			sq. yd.	1	=	1	=	144
		sq. rd.	1	=	9	=	1,296
	R	1	=	30¼	=	272¼	=	39,204
A	1	=	40	=	1,210	=	10,890	=	1,568,160
sq. mi.	1	=	4	=	160	=	4,840	=	43,560	=	6,272,640
1	= 640	= 2,560	= 102,400	= 3,097,600	= 27,878,400	= 4,014,489,600

Scale—ascending, 144, 9, 30¼, 40, 4, 640; descending, 640, 4, 40, 30¼, 9, 144.

Cubic Measure

1,728 cubic inches (cu. in.) make 1 cubic foot (cu. ft.)
27 cubic feet make 1 cubic yard (cu. yd.)
40 cubic feet of round timber or } make 1 ton or load (T)
5 cubic feet of hewn timber }
16 cubic feet make 1 cord foot (cd. ft.)
8 cord feet or } make 1 cord of wood (Cd.)
128 cubic feet }
24¾ cubic feet make 1 perch of stone masonry or(Pch.)

Scale—Most of the unit equivalents are fractional except 1,728 and 27, and are therefore omitted.

Board Measure

1 board 1 in. thick×1 ft. wide×1 ft. long = 1 ft. board measure (B. M.)
1 board 2 in. thick×1 ft. wide×1 ft. long = 2 ft. board measure
1 board ½ in. thick×1 ft. wide×1 ft. long = 1 ft. board measure
etc.

Liquid Measure

4 gills (gi.)	make 1 pint (pt.)
2 pints	make 1 quart (qt.)
4 quarts	make 1 gallon (gal.)*
31½ gallons	make 1 barrel (bbl.)
2barrels or 63 gallons	make 1 hogshead (hhd.)

Unit equivalents

			—pt.	gi.
		qt.	1 =	4
	gal.	1 = 2 =	8
bbl.	1 = 4 = 8 =	32
hhd.	1 = 31½ = 126 = 252 =	1,008
	1 = 2 = 63 = 252 = 504 =	2,016

Scale—ascending, 4, 2, 4, 31½, 2; descending, 2, 31½, 4, 2, 4.

Dry Measure

2 pints (pt.) make 1 quart (qt.)
8 quarts   make 1 peck (pk.)
4 pecks   make 1 bushel (bu.)*

Unit equivalents

```
       qt.  pt.
pk.  1 = 2
bu.  1 = 8 = 16
     1 = 4 = 32 = 64
```

Scale—ascending, 2, 8, 4; descending, 4, 8, 2.

Avoirdupois Weight

16 drachms (dr.) or 437.5 grains (gr.) make 1 ounce (oz.)
16 ounces   make 1 pound (lb.)
100 pounds   make 1 hundred weight (cwt.)
2,000 pounds   make 1 short ton
2,240 pounds   make 1 long ton

Unit equivalents

```
             oz.       dr.
      lb.   1   =    16
cwt.  1 =  16   =   256
T.    1 = 100 = 1,600 = 25,600
      1 = 20 = 2,000 = 32,000 = 512,000
```

Scale—ascending, 16, 16, 100, 20; descending, 20, 100, **16, 16.**

Long Ton Table

28 lbs.   make 1 quarter (qr.)
4 quarters   make 1 hundred weight (cwt.)
20 hundred weight make 1 ton (T.)

```
           gr.   lbs.
cwt.  1   =  28
T.    1 =  4 = 112
      1 = 20 = 80 = 2,240
```

---

*NOTE.—There are two kinds of gallons: the U. S. gallon = **231** cu. ins.; the British Imperial gallon = **227.418** cu. ins.

Scale—ascending, 28, 4, 20; decending, 20, 4, 28.

Circular Measure

60 seconds (") make 1 minute (')
60 minutes   make 1 degree (°)
30 degrees   make 1 sign (S)
360 degrees   make 1 circle (C)

Unit equivalents

$$
\begin{array}{c}
^{\circ}\quad 1 = 60' \\
S\quad 1 = 60 = 3{,}600'' \\
C\quad 1 = 30 = 1{,}800 = 108{,}000 \\
1 = 12 = 360 = 21{,}600 = 1{,}296{,}000
\end{array}
$$

Scale—ascending, 60, 60, 30, 12; descending, 12, 30, 60, 60.
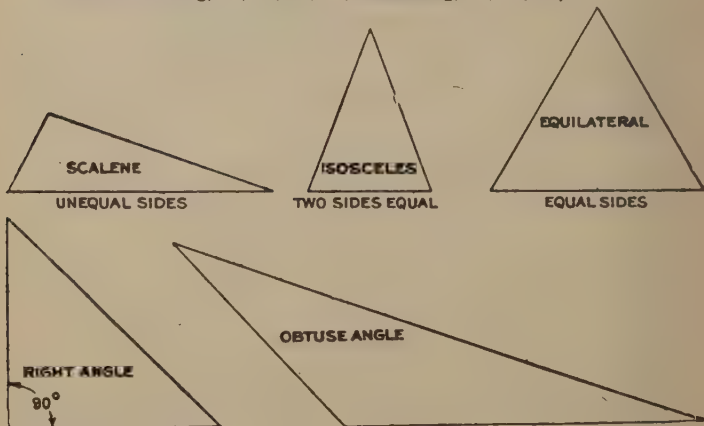
FIGS. 5,843 to 5,847.—Various triangles. A triangle is a polygon having three sides and three angles. By altering the angles and sides a great variety of triangles may be obtained.

Mensuration

Mensuration is the process of measuring things which

occupy space; for instance, find the length of a line, area of triangle, volume of a cube, etc.

$$\begin{cases} \overline{AB}^2 + \overline{AC}^2 = BC^2 \\ 16 + 9 = 25 \end{cases}$$

$$\begin{cases} BC = \sqrt{\overline{AB}^2 + \overline{AC}^2} \\ 5 = \sqrt{16 + 9} = \sqrt{25} = 5 \end{cases}$$

$$\begin{cases} AB = \sqrt{\overline{BC}^2 - \overline{AC}^2} \\ 4 = \sqrt{25 - 9} = \sqrt{16} = 4 \end{cases}$$

$$\begin{cases} AC = \sqrt{\overline{BC}^2 - \overline{AB}^2} \\ 3 = \sqrt{25 - 16} = \sqrt{9} = 3 \end{cases}$$
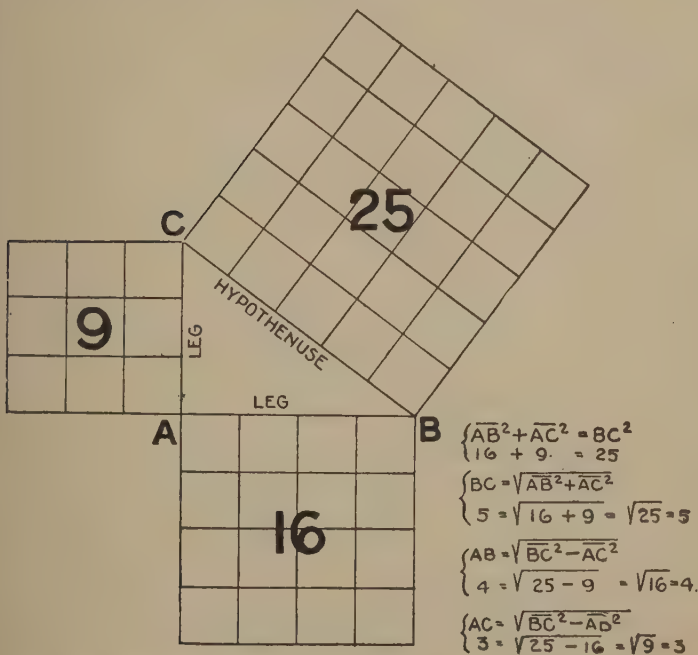
Fig. 5,848.—Right angle triangle showing mathematical relations.

Triangles.—Figures bounded by three sides are called triangles; there are numerous kinds due to varying the angles and length of sides.

1. To find length of hypothenuse of a right triangle,

Rule.—*Hypothenuse is equal to the square root of the sum of the squares of each leg*, as shown in fig. 5,848.

2. To find length of either leg of a right angle,

Rule.—*Either leg is equal to the square root of the difference between square of hypothenuse and the other leg* (fig. 5,848).

3. To find area of any triangle,

Rule.—*Multiply the base by half the perpendicular height.*
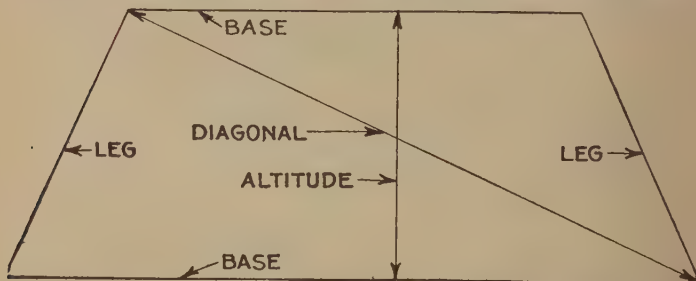
Fig. 5,849.—Quadrilateral illustrating legs, bases, etc. The parallel sides are the *bases* the distance between the bases, the *altitude*, a line joining two opposite vertices, a *diagonal*.

Thus if base be 12 ft. and height 8 ft., area = ½ of 8 × 12 = 48 sq. ft.

Quadrilateral.—Any plain figure bounded by four sides is a quadrilateral, as shown in figs. 5,850 to 5,857.

1. To find the area of a trapezium,

Rule.—1. *Join two of its opposite angles, and thus divide it into two triangles.* 2. *Measure this line and call it the base of each triangle.* 3. *Measure the perpendicular height of each triangle above the base line.* 4. *Then find the area of each triangle by the previous rule; their sum is the area of the whole figure.*
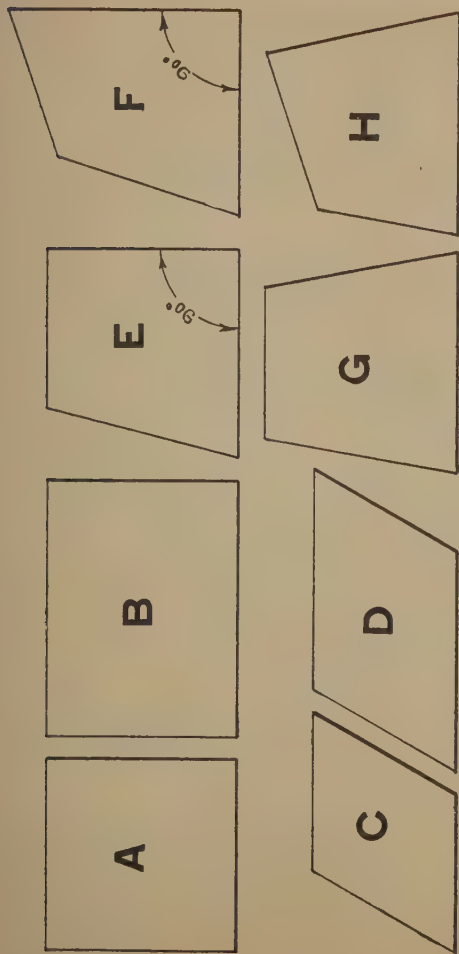
Figs. 5,850 to 5,857.—Various quadrilaterals. **A**, square; **B**, rectangle; **C**, rhombus; **D**, rhomboid; 2, *some sides not parallel.* **E**, trapezoid; **F**, right trapezoid; **G**, isosceles trapezium; **H**, trapezium.

2. To find the area of a trapezoid,

Rule.—*Multiply half the sum of the two parallel sides by the perpendicular distance between them.*

3. To find the area of a square,

Rule.—*Multiply the base by the height; that is, multiply the length by the breadth.*

4. To find the area of a rectangle,

Rule.—*Multiply the length by the breadth.*

5. To find the area of a parallelogram,

Rule.—*Multiply the base by the perpendicular height.*

Polygons.—These comprise the numerous figures having more than four sides, named according to number of sides, thus:

pentagon. .5 sides heptagon. .7 sides nonagon. .9 sides
hexagon. . .6 sides octagon. . . .8 sides decagon. .10 sides
etc.

Angles Between Sides of Polygons

Number of sides	5	6	7	8	9	10
Angle	70°	60°	50°	45°	40°	35°

1. To find the area of a polygon,

Rule.—*Multiply the sum of the sides, or perimeter of the polygon, by the perpendicular dropped from its center to one of its sides, and half the product will be the area.* This rule applies to all regular polygons.

2. To find the area of any regular polygon when length of side only is given.

Rule.—*Multiply the square of the sides by the figure for "area, side = 1" opposite to the polygon in the table following:*

Table of Regular Polygons

Number of sides	3	4	5	6	7	8	9	10	11	12
Area when side = 1	.433	1.	1.721	2.598	3.634	4.828	6.181	7.694	9.366	11.196

The Circle.—The Greek letter π, called pi, is used to represent 3.1416, the circumference of a circle whose diameter is 1. The circumference of a circle equals the diameter multiplied by 3.1416, nearly. Another approximate proportion is $\frac{7}{22}$, and another still nearer is $\frac{355}{113}$.

Why the decimal .7854 is used to calculate the area of a circle is explained in figs. 5,858 and 5,859. The difference between chord sector and segment should be noted as shown in fig. 5,860.
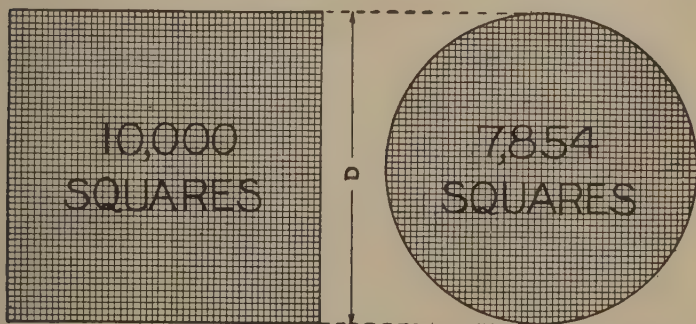
FIGS. 5,858 and 5,859.—Diagram illustrating why the decimal .7854 is used to find the area of a circle. If the square be divided into 10,000 parts or small squares, a circle having a diameter D, equal to a side of the large square will contain 7,854 small squares, hence, if the area of the large square be 1 sq. in., then the area of the circle will be 7854 ÷ 10,000 or .7854 sq. ins., that is, area of the circle $= .7854 \times D \times D = .7854 \times 1 \times 1 = .7854$ sq. ins.

1. To find the circumference of a circle,

Rule.—*Multiply 3.1416 by the diameter.*

2. To find the diameter of a circle (circumference given),

Rule.—*Divide the circumference by 3.1416.*

3. To find the area of a circle,

Rule.—*Multiply the square of the diameter by .7854.* See figs. 5,858 and 5,859.
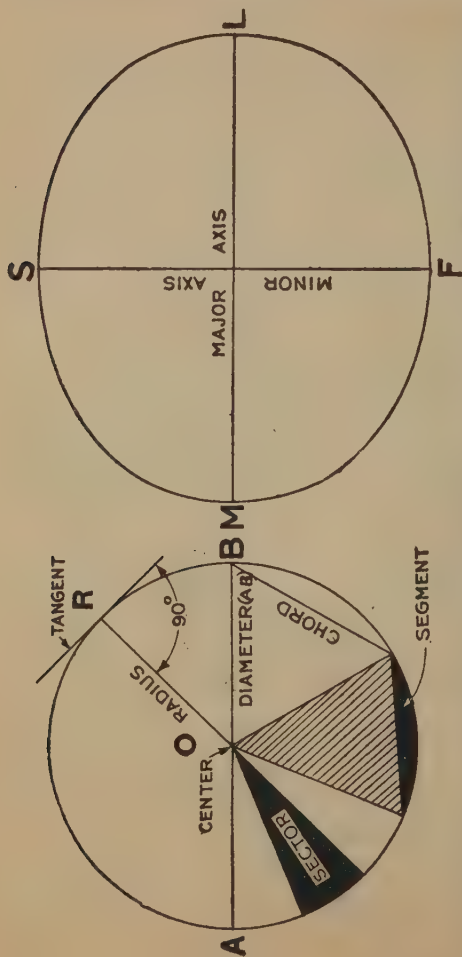
FIGS. 5,860 and 5,861.—Curved figures. Fig. 5,860, circle; fig. 5,861, ellipse. *A circle* is a plane figure bounded by a uniformly curved line, every point of which is equidistant from a point O, within called the center. OR, is a radius and AB, a diameter. The figure also illustrates a sector, segment, and chord. *An ellipse* is a curved figure enclosed by a curved line which is such that the sum of the distances between any point on the circumference and the two foci is invariable. ML, major axis; SF, minor axis.

4. To find the diameter of a circle (area given),

Rule.—*Extract the square root of the area divided by .7854.*

5. To find the area of a sector of a circle,

Rule.—*Multiply the arc of the sector by half the radius.*

6. To find the area of a segment of a circle,

Rule.—*Find the area of the sector which has the same arc and also the area of the triangle formed by the radii and chord; take the sum of these areas if the segment be greater than 1800; take the difference if less.*

7. To find the area of a ring,

Rule.—*Take the difference between the areas of the two circles.*

8. To find the area of an ellipse,

Rule.—*Multiply the product of the two diameters by .7854.*

Relation of the circle to its equal, inscribed and circumscribed squares.

Properties of the Circle

(According to Kent)

Diameter of circle	× .88623 ⎫	
Circumference of circle	× .28209 ⎬	= side of equal square
Circumference of circle	×1.1284	= perimeter of equal square
Diameter of circle	× .7071 ⎫	
Circumference of circle	× .22508 ⎬	= side of inscribed square
Area of circle × .90031	÷ diameter ⎭	
Area of circle	×1.2732	= area of circumscribed square
Area of circle	× .63662	= area of inscribed square
Side of square	×1.4142	= diam. of circumscribed circle
Side of square	×4.4428	= circum.
Side of square	×1.1284	= diam. of equal circle
Side of square	×3.5449	= circum. of equal circle
Perimeter of square	× .88623	= circum. of equal circle
Square inches	×1.2732	= circular inches

Solids.—Finding the volume of solids involves the multiplication of three dimensions: length, breadth and thickness; the surface, two dimensions.

1. To find the volume of a solid,

Rule.—*Multiply the area of the base by the perpendicular height.*

2. To find the volume of a rectangular solid,

Rule.—*Multiply the length, breadth and height together.*

3. To find the surface of a cylinder,

Rule.—*Multiply 3.1416 by the diameter and by the length.*

4. To find the volume of a cylinder,

Rule.—*Multiply .7854 by diameter square of the base and by length of the cylinder.*

5. To find the surface of a sphere,

Rule.—*Multiply area of its great circle by 4.*

6. To find the volume of a sphere,

Rule.—*Multiply .7854 by the cube of the diameter, and then take ⅔ of the product.*

7. To find the volume of a segment of a sphere,

Rule.—*To three times the square of the radius of the segment's base, add the square of the depth or height; then multiply this sum by the depth, and the product by .5236.*

8. To find the surface of a cylindrical ring,

Rule.—*To the thickness of the ring, add the inner diameter; and this sum being multiplied by the thickness, and the product again by 9.8696.*

9. To find the volume of a cylindrical ring,

Rule.—*To the thickness of the ring, add the inner diameter;*

and this sum being multiplied by the square of the thickness, and the product again by 2.4674.

10. To find the slant area of a cone,

Rule.—*Multiply* 3.1416 *by diameter of base and by one-half the slant height.*

11. To find the (slant) area of the frustrum of a cone,

Rule.—*Multiply half the slant height by the sum of the circumferences.*

12. To find the volume of a cone,

Rule.—*Multiply the area of the base by the perpendicular height, and by* $\frac{1}{3}$.

13. To find the volume of a frustrum of a cone,

Rule.—*Find the sum of the squares of the two diameters* (d, D), *add to this the product of the two diameters multiplied by* .7854, *and by one-third the height* (h).

14. To find the volume of a pyramid,

Rule.—*Multiply the area of the base by one-third of the perpendicular height.*

15. To find the volume of a rectangular solid,

Rule.—*Multiply length, breadth and thickness together.*

16. To find the volume of a rectangular wedge,

Rule.—*Find the area of one of the triangular ends and multiply by distance between ends.*

Mensuration of Surfaces and Volumes

(*Summary*)

Area of rectangle = length × breadth.

Area of triangle = base × ½ perpendicular height.

Diameter of circle = radius × 2.

Circumference of circle = diameter × 3.1416.   See table on page 2,677.

Area of circle = square of diameter × .7854.   See table on page 2,676.

Area of sector of circle = $\dfrac{\text{area of circle} \times \text{number of degrees in arc}}{360}$

Area of surface of cylinder = circumference × length + area of two ends.

To find diameter of circle having given area: Divide the area by .7854, and extract the square root.

To find the volume of a cylinder: Multiply the area of the section in square inches by the length in inches = the volume in cubic inches.   Cubic inches divided by 1728 = volume in cubic feet.

Surface of a sphere = square of diameter × 3.1416.

Solidity of a sphere = cube of diameter × .5236.

Side of an inscribed cube = radius of a sphere × 1.1547.

Area of the base of a pyramid or cone, whether round, square or triangular, multiplied by one-third of its height = the solidity.

Diam. × .8862 = side of an equal square.

Diam. × .7071 = side of an inscribed square.

Radius × 6.2832 = circumference.

Circumference = 3.5446 × $\sqrt{\text{Area of circle}}$.

Diameter = 1.1283 × $\sqrt{\text{Area of circle}}$

Length of arc = No. of degrees × .017453 radius.

Degrees in arc whose length equals radius = 57° 2958'.

Length of an arc of 1° = radius × .017453.

"   "   "   1 Min. = radius × .0002909.

"   "   "   1 Sec. = radius × .0000048.

p = Proportion of circumference to diameter = 3.1415926.

p^2 = 9.8696044.

$p\sqrt{}$ = 1.7724538.

Log. = 0.49715.

1/p = 0.31831.

1/360 = .002778.

360/p = 114.59.

Lineal feet.......................... ×	.00019	= Miles.
" yards....................... ×	.0006	= "
Square inches....................... ×	.007	= Square feet.

Square feet.......................×	.111	=Square yards.
" yards......................×	.0002067	=Acres.
Acres............................×4840		=Square yards.
Cubic inches.....................×	.00058	=Cubic feet.
" feet.....................×	.03704	=Cubic yards.
Circular inches..................×	.00546	=Square feet.
Cyl. inches......................×	.0004546	=Cubic feet.
" feet.....................×	.02909	= " yards.
Links............................×	.22	=Yards.
" ....×	.66	=Feet.
Feet.............................×	1.5	=Links.
Width in chains..................×	8	=Acres per mile.
183346 circular in................		=1 square foot.
2200 Cylindrical in...............		=1 cubic foot.
Cubic feet.......................×	7.48	=U. S. gallons.
" inches...................×	.004329	=U. S. gallons.
U. S. gallons....................×	.13367	=Cubic feet.
U. S. " ....× 231		= " inches.
Cubic feet.......................×	.8036	=U. S. bushel.
" inches...................×	.000466	= " " "
Cyl. feet of water...............×	6	=U. S. gallons.
Lbs. Avoir.......................×	.009	=cwt. (112)
" " ....×	.00045	=Tons (2240)
Cubic feet of water..............×	62.5	=Lbs. Avoir.
" inch " " ....×	.03617	= " "
Cyl. feet water..................×	49.1	= " "
Cyl. inch water..................×	.02842	= " "
13.44 U. S. gallons of water.........		=1 cwt.
268.8 U. S. " " "		=1 ton.
1.8 cubic feet of water..............		=1 cwt.
35.88 cubic feet of water............		=1 ton.
Column of water, 12 inches high, and 1 inch in diameter = .341 Lbs.		
U. S. bushel.....................×	.0495	=Cubic yards.
" " " ....×	1.2446	= " feet.
" " " ....×2150.42		=inches.

Rule.—1. *Divide the irregular solid into different figures; and the sum of their solidities, found by the preceding problems, will be the solidity required.* 2. *If the figure be a compound solid, whose two ends are equal plane figures, the solidity may be found by multiplying the area of one end by the length.* 3. *To find the*

solidity of a piece of wood or stone that is craggy or uneven, put it into a tub or cistern, and pour in as much water as will just cover it; then take it out and find the contents of that part of the vessel through which the water has descended and it will be the solidity required.

17. To find the surface and volume of any of the five regular solids figs. 5,862 to 5,866.
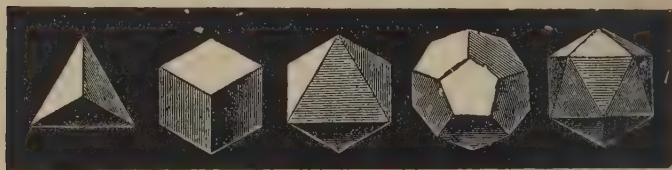
Figs. 5,862 to 5,866.—The five regular solids. Tetrahedron or solid, bounded by four equilateral triangles; fig. 5,862, hexahedron, or cube, bounded by six squares; fig. 5,863, octahedron, bounded by eight equilateral triangles; fig. 5,864, dodecahedron, bounded by twelve pentagons; fig. 5,865, icosahedron, bounded by twenty equilateral triangles.

Rule (surface).—*Multiply the tabular area below, by the square of the edge of the solid.*

Rule (volume).—*Multiply the tabular contents below, by the cube of the given edge.*

Surfaces and Volumes of Regular Solids

Number of Sides	NAME	Area. Edge = 1	Contents. Edge = 1
4	.....Tetrahedron........	1.7320	0.1178
6	.....Hexahedron..... ..	6.0000	1.0000
8	.....Octahedron.........	3.4641	0.4714
12	.....Dodecahedron......	20.6458	7.6631
20	.....Icosahedron.........	8.6603	2.1817

Trigonometrical Functions.—Every triangle has six parts: 3 sides and 3 angles. When any three of these parts are given,

provided one of them be a side, the other parts may be determined. Fig. 5,867 illustrates the parts considered in expressing trigonometrical functions. It will be noted in this triangle that angle ABO = 90°. In this triangle the trigonometrical functions, expressed as ratios are as follows:

$$\textit{Sine} \text{ of the angle } \theta = \frac{AB}{AO} = \frac{\text{opposite side}}{\text{hypothenuse}}$$
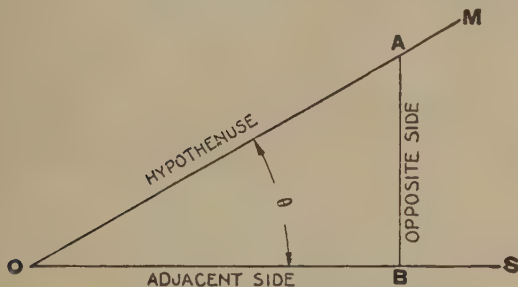
Fɪɢ. 5,867.—Angle θ and constructed triangle A,O,B, for expressing trigonometrical functions as ratios.

$$\textit{Cosine} \text{ of the angle } \theta = \frac{OB}{OA} = \frac{\text{adjacent side}}{\text{hypothenuse}}$$

$$\textit{Tangent} \text{ of the angle } \theta = \frac{AB}{OB} = \frac{\text{opposite side}}{\text{adjacent side}}$$

$$\textit{Cotangent} \text{ of the angle } \theta = \frac{OB}{AB} = \frac{\text{adjacent side}}{\text{opposite side}}$$

$$\textit{Secant} \text{ of the angle } \theta = \frac{OA}{OB} = \frac{\text{hypothenuse}}{\text{adjacent side}}$$

$$\textit{Cosecant} \text{ of the angle } \theta = \frac{OA}{AB} = \frac{\text{hypothenuse}}{\text{opposite side}}$$

For the sake of brevity the names of the functions are contracted, thus: for *sine* θ, write *sin* θ for cosine θ, write *cos* θ, etc.

The cosine, cotangent (cot.) and cosecant (cosec) of an angle are respectively the sine, tangent and secant of the complement of that angle.

Natural Trigonometrical Functions.—These are virtually ratios but by taking what corresponds to the hypothenuse OA, of the triangle AOB, in fig. 5,867 as a *radius of unity length* of a circle the denominators of the ratios are unity or 1, and disappear leaving only the numerators, that is, a line
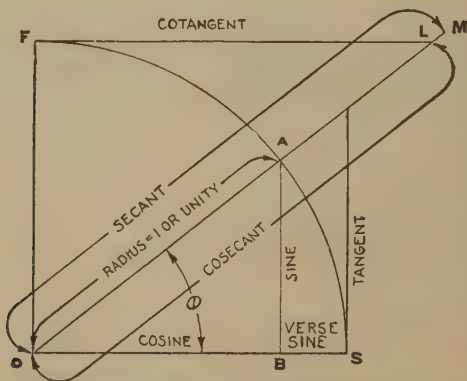
Fɪɢ. 5,868.—*Natural trigonometrical functions*, or functions expressed as lines. These natural trigonometrical functions help considerably with the aid of tables, to facilitate calculations.

instead of a ratio or function; these lines are the so called *"natural functions,"* thus in fig. 5,868:

$$\textbf{\textit{Sine}} \text{ angle } \theta = \frac{AB}{\text{radius}} = \frac{AB}{1} = AB$$

Cosine angle $\theta = \dfrac{OB}{\text{radius}} = OB$

Tangent angle $\theta = \dfrac{MS}{OS} = \dfrac{MS}{\text{radius}} = MS$
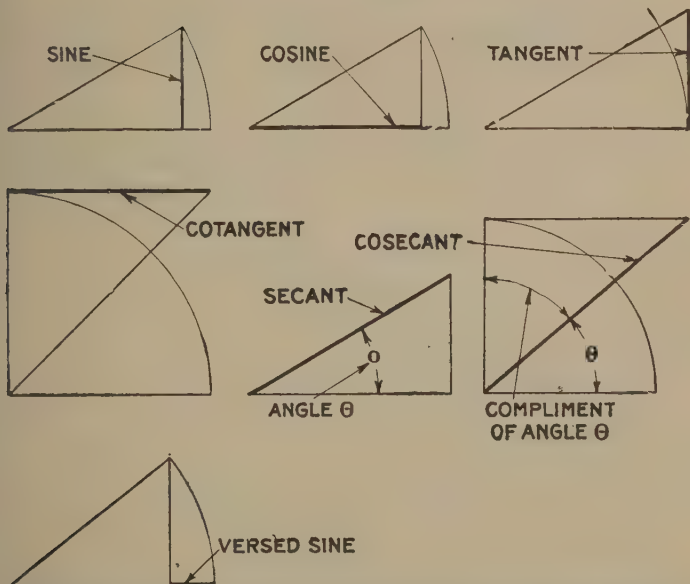
FIGS. 5,869 to 5,875.—The natural trigonometrical functions each shown separately for clearness. *As elsewhere stated* the cos., cot, and cosec. of an angle are respectively the sine, tan, and sec. of the complement of the angle.

Cotangent angle θ = tangent of complement of angle

$$\theta = \frac{OM}{OF} = \frac{OM}{\text{radius}} = OM$$

Secant angle $\theta = \dfrac{OM}{OS} = \dfrac{OM}{\text{radius}} = OM$

Cosecant angle θ = secant of complement angle $\theta = \dfrac{OL}{OF} = \dfrac{OL}{radius} = OL$

Versed sine angle $\theta = \dfrac{BS}{OS} = \dfrac{BS}{radius} = BS$

The natural trigonometrical functions are the ones of value in ordinary calculations and should be thoroughly understood.
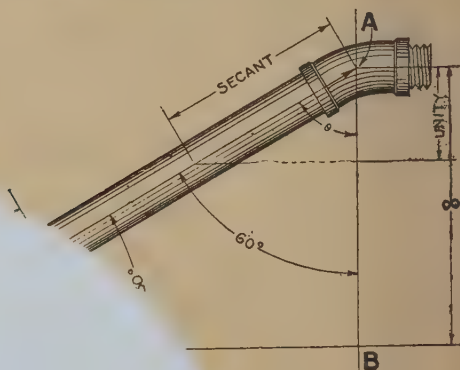
...lbow illustrating use of natural ...connecting pipe.

...le on page 2,675 as

...part are to be connected ...fset OB and connecting

...th offset OB = 1.73 × 8 =

...ing pipe OA = 8 × 2 = 16 ins.

Mathematical Tables.—The various tables which follow are for convenient reference and will be found useful in numerous calculations.

Natural Trigonometrical Functions

Degree	Sine	Cosine	Tangent	Secant	Degree	Sine	Cosine	Tangent	Secant
0	.00000	1.0000	.00000	1.0000	46	.7193	.6947	1.0355	1.4395
1	.01745	.9998	.01745	1.0001	47	.7314	.6820	1.0724	1.4663
2	.03490	.9994	.03492	1.0006	48	.7431	.6691	1.1106	1.4945
3	.05234	.9986	.05241	1.0014	49	.7547	.6561	1.1504	1.5242
4	.06976	.9976	.06993	1.0024	50	.7660	.6428	1.1918	1.5557
5	.08716	.9962	.08749	1.0038	51	.7771	.6293	1.2349	1.5890
6	.10453	.9945	.10510	1.0055	52	.7880	.6157	1.2799	1.6243
7	.12187	.9925	.12278	1.0075	53	.7986	.6018	1.3270	1.6616
8	.1392	.9903	.1405	1.0098	54	.8090	.5878	1.3764	1.7013
9	.1564	.9877	.1584	1.0125	55	.8192	.5736	1.4281	1.7434
10	.1738	.9848	.1763	1.0154	56	.8290	.5592	1.4826	1.7883
11	.1908	.9816	.1944	1.0167	57	.8387	.5446	1.5399	1.8361
12	.2079	.9781	.2126	1.0223	58	.8480	.5299	1.6003	1.8871
13	.2250	.9744	.2309	1.0263	59	.8572	.5150	1.6643	1.9416
14	.2419	.9703	.2493	1.0306	60	.8660	.5000	1.7321	2.0000
15	.2588	.9659	.2679	1.0353	61	.8746	.4848	1.8040	2.0627
16	.2756	.9613	.2867	1.0403	62	.8829	.4695	1.8807	2.1300
17	.2924	.9563	.3057	1.0457	63	.8910	.4540	1.9626	2.2027
18	.3090	.9511	.3249	1.0515	64	.8988	.4384	2.0503	2.2812
19	.3256	.9455	.3443	1.0576	65	.9063	.4226	2.1445	2.3662
20	.3420	.9397	.3640	1.0642	66	.9135	.4067	2.2460	2.4586
21	.3584	.9336	.3839	1.0711	67	.9205	.3907	2.3559	2.5593
22	.3746	.9272	.4040	1.0785	68	.9272	.3746	2.4751	2.6695
23	.3907	.9205	.4245	1.0864	69	.9336	.3584	2.6051	2.7904
24	.4067	.9135	.4452	1.0946	70	.9397	.3420	2.7475	2.9238
25	.4226	.9063	.4663	1.1034	71	.9455	.3256	2.9042	3.0715
26	.4384	.8988	.4877	1.1126	72	.9511	.3090	3.0777	3.2361
27	.4540	.8910	.5095	1.1223	73	.9563	.2924	3.2709	3.4203
28	.4695	.8829	.5317	1.1326	74	.9613	.2756	3.4874	3.6279
29	.4848	.8746	.5543	1.1433	75	.9659	.2588	3.7321	3.8637
30	.5000	.8660	.5774	1.1547	76	.9703	.2419	4.0108	4.1336
31	.5150	.8572	.6009	1.1666	77	.9744	.2250	4.3315	4.4454
32	.5299	.8480	.6249	1.1792	78	.9781	.2079	4.7046	4.8097
33	.5446	.8387	.6494	1.1924	79	.9816	.1908	5.1446	5.2408
34	.5592	.8290	.6745	1.2062	80	.9848	.1736	5.6713	5.7588
35	.5736	.8192	.7002	1.2208	81	.9877	.1564	6.3138	6.3924
36	.5878	.8090	.7265	1.2361	82	.9903	.1392	7.1154	7.1853
37	.6018	.7986	.7536	1.2521	83	.9925	.12187	8.1443	8.2055
38	.6157	.7880	.7813	1.2690	84	.9945	.10453	9.5144	9.5668
39	.6293	.7771	.8098	1.2867	85	.9962	.08716	11.4301	11.474
40	.6428	.7660	.8391	1.3054	86	.9976	.06976	14.3007	14.335
41	.6561	.7547	.8693	1.3250	87	.9986	.05234	19.0811	19.107
42	.6691	.7431	.9004	1.3456	88	.9994	.03490	28.6363	28.654
43	.6820	.7314	.9325	1.3673	89	.9998	.01745	57.2900	57.299
44	.6947	.7193	.9657	1.3902	90	1.0000	Inf.	Inf.	Inf.
45	.7071	.7071	1.0000	1.4142	—	—	—	—	—

Areas of Circles

Diameter.	Area.	Diameter.	Area.	Diameter.	Area.	Diameter.	Area.
$\frac{1}{8}$	0.0123	10	78.54	30	706.86	65	3318.3
$\frac{1}{4}$	0.0491	$10\frac{1}{2}$	86.59	31	754.76	66	3421.2
$\frac{3}{8}$	0.1104	11	95.03	32	804.24	67	3525.6
$\frac{1}{2}$	0.1963	$11\frac{1}{2}$	103.86	33	855.30	68	3631.6
$\frac{5}{8}$	0.3068	12	113.09	34	907.92	69	3739.2
$\frac{3}{4}$	0.4418	$12\frac{1}{2}$	122.71	35	962.11	70	3848.4
$\frac{7}{8}$	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	$13\frac{1}{2}$	143.13	37	1075.2	72	4071.5
$1\frac{1}{8}$	0.9940	14	153.93	38	1134.1	73	4185.4
$1\frac{1}{4}$	1.227	$14\frac{1}{2}$	165.13	39	1194.5	74	4300.8
$1\frac{3}{8}$	1.484	15	176.71	40	1256.6	75	4417.8
$1\frac{1}{2}$	1.767	$15\frac{1}{2}$	188.69	41	1320.2	76	4536.4
$1\frac{5}{8}$	2.073	16	201.06	42	1385.4	77	4656.6
$1\frac{3}{4}$	2.405	$16\frac{1}{2}$	213.82	43	1452.2	78	4778.3
$1\frac{7}{8}$	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	$17\frac{1}{2}$	240.52	45	1590.4	80	5026.5
$2\frac{1}{4}$	3.976	18	254.46	46	1661.9	81	5153.0
$2\frac{1}{2}$	4.908	$18\frac{1}{2}$	268.80	47	1734.9	82	5281.0
$2\frac{3}{4}$	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	$19\frac{1}{2}$	298.64	49	1885.7	84	5541.7
$3\frac{1}{4}$	8.295	20	314.16	50	1963.5	85	5674.5
$3\frac{1}{2}$	9.621	$20\frac{1}{2}$	330.06	51	2042.8	86	5808.8
$3\frac{3}{4}$	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	$21\frac{1}{2}$	363.05	53	2206.1	88	6082.1
$4\frac{1}{2}$	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	$22\frac{1}{2}$	397.60	55	2375.8	90	6361.7
$5\frac{1}{2}$	23.758	23	415.47	56	2463.0	91	6503.9
6	28.274	$23\frac{1}{2}$	433.73	57	2551.7	92	6647.6
$6\frac{1}{2}$	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	$24\frac{1}{2}$	471.43	59	2733.9	94	6939.8
$7\frac{1}{2}$	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
$8\frac{1}{2}$	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
$9\frac{1}{2}$	70.882	29	660.52	64	3216.9	99	7697.7

Circumferences of Circles

Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	Circumference.
1/8	.3927	10	31.41	30	94.24	65	204.2
1/4	.7854	10 1/2	32.98	31	97.38	66	207.3
3/8	1.178	11	34.55	32	100.5	67	210.4
1/2	1.570	11 1/2	36.12	33	103.6	68	213.6
5/8	1.963	12	37.69	34	106.8	69	216.7
3/4	2.356	12 1/2	39.27	35	109.9	70	219.9
7/8	2.748	13	40.84	36	113.0	71	223.0
1	3.141	13 1/2	42.41	37	116.2	72	226.1
1 1/8	3.534	14	43.98	38	119.3	73	229.3
1 1/4	3.927	14 1/2	45.55	39	122.5	74	232.4
1 3/8	4.319	15	47.12	40	125.6	75	235.6
1 1/2	4.712	15 1/2	48.69	41	128.8	76	238.7
1 5/8	5.105	16	50.26	42	131.9	77	241.9
1 3/4	5.497	16 1/2	51.83	43	135.0	78	245.0
1 7/8	5.890	17	53.40	44	138.2	79	248.1
2	6.283	17 1/2	54.97	45	141.3	80	251.3
2 1/4	7.068	18	56.54	46	144.5	81	254.4
2 1/2	7.854	18 1/2	58.11	47	147.6	82	257.6
2 3/4	8.639	19	59.69	48	150.7	83	260.7
3	9.424	19 1/2	61.26	49	153.9	84	263.8
3 1/4	10.21	20	62.83	50	157.0	85	267.0
3 1/2	10.99	20 1/2	64.40	51	160.2	86	270.1
3 3/4	11.78	21	65.97	52	163.3	87	273.3
4	12.56	21 1/2	67.54	53	166.5	88	276.4
4 1/2	14.13	22	69.11	54	169.6	89	279.6
5	15.70	22 1/2	70.68	55	172.7	90	282.7
5 1/2	17.27	23	72.25	56	175.9	91	285.8
6	18.84	23 1/2	73.82	57	179.0	92	289.0
6 1/2	20.42	24	75.39	58	182.2	93	292.1
7	21.99	24 1/2	76.96	59	185.3	94	295.3
7 1/2	23.56	25	78.54	60	188.4	95	298.4
8	25.13	26	81.68	61	191.6	96	301.5
8 1/2	26.70	27	84.82	62	194.7	97	304.7
9	28.27	28	87.96	63	197.9	98	307.8
9 1/2	29.84	29	91.10	64	201.0	99	311.0

EQUIVALENTS OF WEIGHTS AND MEASURES ACCORDING TO UNITED STATES AND METRIC SYSTEMS

1 pound (lb.)	453.6 grammes
100 lbs.	45.36 kilos
112 lbs.	50.80 kilos
1 net ton (2,000 lbs.)	907.2 kilos
1 gross ton (2,240 lbs.)	1,016 kilos
1 kilo	2.2046 lbs.
100 kilos	220.46 lbs.
1 metric ton (1,000 kilos)	2,204.6 lbs., 0.9842 gross ton, 1.1023 net ton
1 inch	25.40 millimetres
1 foot (12 inches)	30.48 centimetres
1 yard (3 feet)	91.44 centimetres
1 mile (1,760 yards)	1,609.35 metres
1 millimetre	0.03937 inch
1 centimetre	0.3937 inch
1 metre	39.37 inches, 3.2808 feet
1 kilometre	0.62137 mile, 1,093.6 yards
1 square inch	6.4516 square centimetres / 645.16 square millimetres
1 square foot	0.0929 square metre
1 square yard	0.8361 square metre
1 square millimetre	0.00155 square inch
1 square centimetre	0.155 square inch
1 square metre	10.7639 square feet / 1.196 square yards
1 pound per foot....................	1.4882 kilos per metre
1 pound per yard....................	0.4961 kilos per metre
1 pound per square inch.............	0.0703 kilos per square centimetre
1 pound per square foot.............	4.8825 kilos per square metre
1 kilo per metre....................	0.6720 pounds per foot
1 kilo per square millimetre..........	1,422.32 pounds per square inch
1 kilo per square centimetre.........	14.2232 pounds per square inch
1 kilo per square metre.............	0.2048 pounds per square foot / 1.8433 pounds per square yard

Logarithms of Numbers

LOGARITHMS OF NUMBERS (Continued).

No.	0	1	2	3	▥	5	6	7	8	9	Diff.
55	74036	74115	74194	74273	74351	74429	74507	74586	74663	74741	78
56	74819	74896	74974	75051	75128	75205	75282	75358	75435	75511	77
57	75587	75664	75740	75815	75891	75967	76042	76118	76193	76268	76
58	76343	76418	76492	76567	76641	76716	76790	76864	76938	77012	75
59	77085	77159	77232	77305	77379	77452	77525	77597	77670	77743	74
60	77815	77887	77960	78032	78104	78176	78247	78319	78390	78462	72
61	78533	78604	78675	78746	78817	78888	78958	79029	79099	79169	71
62	79239	79309	79379	79449	79518	79588	79657	79727	79796	79865	70
63	79934	80003	80072	80140	80209	80277	80346	80414	80482	80550	69
64	80618	80686	80754	80821	80889	80956	81023	81090	81158	81224	68
65	81291	81358	81425	81491	81558	81624	81690	81757	81823	81889	66
66	81954	82020	82086	82151	82217	82282	82347	82413	82478	82543	66
67	82607	82672	82737	82802	82866	82930	82995	83059	83123	83187	64
68	83251	83315	83378	83442	83506	83569	83632	83696	83759	83822	63
69	83885	83948	84011	84073	84136	84198	84261	84323	84386	84448	63
70	84510	84572	84634	84696	84757	84819	84880	84942	85003	85065	62
71	85126	85187	85248	85309	85370	85431	85491	85552	85612	85673	61
72	85733	85794	85854	85914	85974	86034	86094	86153	86213	86273	60
73	86332	86392	86451	86510	86570	86629	86688	86747	86806	86864	59
74	86923	86982	87040	87099	87157	87216	87274	87332	87390	87448	58
75	87506	87564	87622	87680	87737	87795	87852	87910	87967	88024	58
76	88081	88138	88196	88252	88309	88366	88423	88480	88536	88593	57
77	88649	88705	88762	88818	88874	88930	88986	89042	89098	89154	56
78	89209	89265	89321	89376	89432	89487	89542	89597	89653	89708	55
79	89763	89818	89873	89927	89982	90037	90091	90146	90200	90255	55
80	90309	90363	90417	90472	90526	90580	90634	90687	90741	90795	54
81	90849	90902	90956	91009	91062	91116	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91593	91645	91698	91751	91803	91855	53
83	91908	91960	92012	92065	92117	92169	92221	92273	92324	92376	52
84	92428	92480	92531	92583	92634	92686	92737	92788	92840	92891	52
85	92942	92993	93044	93095	93146	93197	93247	93298	93349	93399	51
86	93450	93500	93551	93601	93651	93702	93752	93802	93852	93902	50
87	93952	94002	94052	94101	94151	94201	94250	94300	94349	94399	50
88	94448	94498	94547	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94988	95036	95085	95134	95182	95231	95279	95328	95376	49
90	95424	95472	95521	95569	95617	95665	95713	95761	95809	95856	48
91	95904	95952	95999	96047	96095	96142	96190	96237	96284	96332	48
92	96379	96426	96473	96520	96567	96614	96661	96708	96755	96802	47
93	96848	96895	96942	96988	97035	97081	97128	97174	97220	97267	47
94	97313	97359	97405	97451	97497	97543	97589	97635	97681	97727	46
95	97772	97818	97864	97909	97955	98000	98046	98091	98137	98182	46
96	98227	98272	98318	98363	98408	98453	98498	98543	98588	98632	45
97	98677	98722	98767	98811	98856	98900	98945	98989	99034	99078	45
98	99123	99167	99211	99255	99300	99344	99388	99432	99476	99520	44
99	99564	99607	99651	99695	99739	99782	99826	99870	99913	99957	44

LOGARITHMS OF NUMBERS.

No.	0	1	2	3	4	5	6	7	8	9	Diff.
10	00000	00432	00860	01284	01703	02119	02531	02938	03342	03743	415
11	04139	04532	04922	05308	05690	06070	06446	06819	07188	07555	379
12	07918	08279	08636	08991	09342	09691	10037	10380	10721	11059	344
13	11394	11727	12057	12385	12710	13033	13354	13672	13988	14301	322
14	14613	14922	15229	15534	15836	16137	16435	16732	17026	17319	298
15	17609	17898	18184	18469	18752	19033	19312	19590	19866	20140	281
16	20412	20683	20952	21219	21484	21748	22011	22272	22531	22789	264
17	23045	23300	23553	23805	24055	24304	24551	24797	25042	25285	249
18	25527	25768	26007	26245	26482	26717	26951	27184	27416	27646	234
19	27875	28103	28330	28556	28780	29003	29226	29447	29667	29885	222
20	30103	30320	30535	30750	30963	31175	31387	31597	31806	32015	212
21	32222	32428	32634	32838	33041	33244	33445	33646	33846	34044	202
22	34242	34439	34635	34830	35025	35218	35411	35603	35793	35984	193
23	36173	36361	36549	36736	36922	37107	37291	37475	37658	37840	185
24	38021	38202	38382	38561	38739	38917	39094	39270	39445	39620	177
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	170
26	41497	41664	41830	41996	42160	42325	42488	42651	42813	42975	164
27	43136	43297	43457	43616	43775	43933	44091	44248	44404	44560	158
28	44716	44871	45025	45179	45332	45484	45637	45788	45939	46090	152
29	46240	46389	46538	46687	46835	46982	47129	47276	47422	47567	147
30	47712	47857	48001	48144	48287	48430	48572	48714	48855	48996	143
31	49136	49276	49415	49554	49693	49831	49969	50106	50243	50379	138
32	50515	50651	50786	50920	51055	51189	51322	51455	51587	51720	134
33	51851	51983	52114	52244	52375	52504	52634	52763	52892	53020	130
34	53148	53275	53403	53529	53656	53782	53908	54033	54158	54283	126
35	54407	54531	54654	54777	54900	55023	55145	55267	55388	55509	122
36	55630	55751	55871	55991	56110	56229	56348	56467	56585	56703	119
37	56820	56937	57054	57171	57287	57403	57519	57634	57749	57864	116
38	57978	58092	58206	58320	58433	58546	58659	58771	58883	58995	113
39	59106	59218	59329	59439	59550	59660	59770	59879	59988	60097	110
40	60206	60314	60423	60531	60638	60746	60853	60959	61066	61172	107
41	61278	61384	61490	61595	61700	61805	61909	62014	62118	62221	104
42	62325	62428	62531	62634	62737	62839	62941	63043	63144	63246	102
43	63347	63448	63548	63649	63749	63849	63949	64048	64147	64246	99
44	64345	64444	64542	64640	64738	64836	64933	65031	65128	65225	98
45	65321	65418	65514	65610	65706	65801	65896	65992	66087	66181	96
46	66276	66370	66464	66558	66652	66745	66839	66932	67025	67117	94
47	67210	67302	67394	67486	67578	67669	67761	67852	67943	68034	92
48	68124	68215	68305	68395	68485	68574	68664	68753	68842	68931	90
49	69020	69108	69197	69285	69373	69461	69548	69636	69723	69810	88
50	69897	69984	70070	70157	70243	70329	70415	70501	70586	70672	86
51	70757	70842	70927	71012	71096	71181	71265	71349	71433	71517	84
52	71600	71684	71767	71850	71933	72016	72099	72181	72263	72346	83
53	72428	72509	72591	72673	72754	72835	72916	72997	73078	73159	81
54	73239	73320	73400	73480	73560	73640	73719	73799	73878	73957	80

Useful Information

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the diameter of a circle, multiply the circumference by .31831.

To find the area of a circle, multiply the square of the diameter by .7854.

To find the surface of a ball (sphere), multiply the square of the diameter by 3.1416.

To find the side of an equal square, multiply the diameter by .8862.

To find the cubic inches (volume) in a ball, multiply the cube of the diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

The radius of a circle × 6.283185 = the circumference.

The square of the diameter of a circle × .7854 = the area.

The square of the circumference of a circle × .07958 = the area.

Half the circumference of a circle × half its diameter = the area.

The circumference of a circle × .159155 = the radius.

The square root of the area of a circle × .56419 = the radius.

The square root of the area of a circle × 1.12838 = the diameter.

A gallon of water (United States Standard) weighs 8⅓ pounds and contains 231 cubic inches. A cu. ft. of water weighs 62½ lbs. and contains 1,728 cu. ins., or 7½ gals.

To find the pressure in lbs. per sq. in. of a column of water, multiply the height of the column in ft. by .434.

Steam rising from water at its boiling point (212 degrees F.) has a pressure equal to that of the atmosphere at sea level (14.7 lbs. per sq. in.).

Each nominal horse power of boilers requires approximately one-half cu. ft. of water per hour.

To find the area of a required pipe, the volume and velocity of water being given, multiply the number of cu. ft. of water by 144, and divide the product by the velocity in ft. per minute.

To find the velocity in ft. per minute necessary to discharge a given volume of water in a given time, multiply the number of cu. ft. of water by 144, and divide the product by the area of the pipe in ins.

CHAPTER 103

Physics for Plumbers

By definition, physics is *the science or group of sciences that treats of the phenomena associated with matter in general, especially in its relations to energy, and of the laws governing these phenomena, excluding the special laws and phenomena peculiar to living matter (biology) or to special kinds of matter (chemistry)*.

Physics is generally held to treat of:

1. The constitution and properties of matter.
2. Mechanics.
3. Acoustics.
4. Heat.
5. Optics.
6. Electricity and magnetism.

As sometimes used in a limited sense, it embraces only the last four divisions; more generally and loosely, it includes all the physical sciences.

According to Barker, physics regards matter solely as the vehicle of energy. And hence from this point of view, physics may be defined as *that department of science whose province it is to investigate all those phenomena of nature which depend either upon the transference of energy from one portion of matter to another, or upon its transformation into any of the forms which it is capable of assuming.* In a word, physics may be regarded as the science of energy, precisely as chemistry may be regarded as the science of matter.

The scope of physics extends considerably beyond that which is of importance to the plumber in the performance of his work, hence only such subjects as will be of use to him will be presented here. In this connection he should thoroughly study this chapter, and should not be satisfied with simply an understanding of why pipes burst in freezing weather or why water circulates in hot water heating systems, but should know the reasons for all various phenomena commonly observed by him in his work, for instance: why pipes become air bound; why air chambers on pumps fill with water; why a boiler water gauge does not register the true water level; why a bucket valve pump delivers more than its displacement, etc.

The importance of some of the matter here given may not be apparent to the student; however it is essential to the workman in the intelligent performance of his work.

Measurements.—Physics begins with measurements, according to Plato, and in fact, "if arithmetic, mensuration and weighing be taken away from any art, that which remains will not be much."

There are three fundamental kinds of measurements:

1. Length.   2. Mass.   3. Time.

In addition to these there are *derived* measurements as measurements of:

1. Area.

2. Volume.

These are called derived because they are the products of two and three lengths respectively. Various units are used for these various measurements. The plumber uses the ordinary unit such as inches, pounds, seconds for fundamental measurements and square inches, cubic inches for the derived measurements.

In addition to measuring the size or weight of an object, other kinds of measurement are necessary in physics, such as the measurement of pressure, temperature, etc.; such measurements are indicated by instruments provided with arbitrary scales divided into standard divisions, each division standing for a unit of pressure, temperature, etc. In the

Carpenters and Builders Guide No. 2 the subject of measurements, including the various tables in use, is treated at such great length that further explanation here is unnecessary.

Measuring Devices.—For ordinary linear measurements such as measuring pipe lengths, the familiar carpenter's two foot four fold rule is commonly used. Owing to the rough usage given to plumbers' tools, cheap and easily broken rules should be avoided. A strong brass bound rule such as shown in fig. 5,877 is desirable. The draughting scales on this rule are ordinarily not necessary, though occasion may arise for their
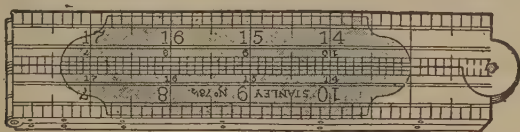
Fig. 5,877.—Stanley two foot four fold box wood rule with double arch joints, full bound drafting scales and graduated into 8ths, 10ths and 16ths inches.
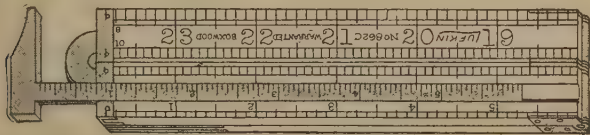
Fig. 5,878.—Lufkin two foot four fold box wood caliper rule, 1⅜ in. wide, arch joint, edge plates. Graduated into 8ths, 10ths and 16ths. *In position shown,* the caliper reads ¹⁵⁄₁₆ or ¾ inch.

use in scaling any measurement that may be omitted on a drawing or blue print. Such scaling is properly the work of the draughtsman and when undertaken by a plumber should be considered as only approximate.

An even more desirable form of the "two foot rule" is the caliper rule as shown in fig. 5,878, which permits the more convenient and precise measurement of pipe diameters, thickness of cast plates, etc.

Since considerable plumbing work is done inside and in poorly lighted places, the so-called blind man's rule or one having very large figures, as in fig. 5,879 will be found desirable.

To use a rule efficiently, do not use a smaller graduation scale than is necessary. That is, in cases where the dimensions can be read close enough with the 8th scale do not use
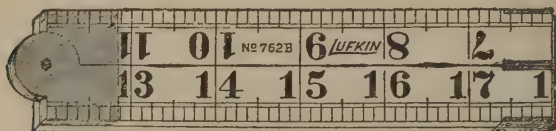
FIG. 5,879.—Lufkin two foot four fold box wood *blind man's* rule with square joint, edge plates, unbound. *Graduations:* 8ths and 16ths. The large and distinct figures are especially adapted for use in poorly lighted places, or by persons with poor eye sight.
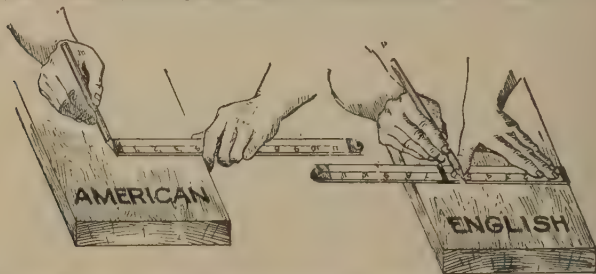
FIGS. 5,880 and 5,881.—Methods of using carpenter's rule with American and English systems of marking. In fig. 5,880 the scale reads backwards so that when held in the left hand, as it should be, the right hand is free to use the marking instrument. *In using* the English system, fig. 5,881, the rule cannot be grasped firmly in the left hand but must first be placed in position on the board and then held by pressing it against the board with the fingers of the left hand, which necessarily cover up some of the figures on the rule.

the 16th scale as the rule can be read quicker with the 8th than with the 16th scale and with less chance of error.

There are two systems of marking for rules, the American and the English, as shown in figs. 5,880 and 5,881.

A rule coming into extensive use is the spring joint multi-fold extension rule as shown in fig. 5,882. Such measuring devices as just described usually answer · the needs of the plumber, however, occasionally and especially the sheet metal worker needs to take small measurements with considerable precision as in measuring the thickness of sheet metal to determine its "gauge number." The measuring instrument used is known as a micrometer caliper, a typical one for general use being shown in fig. 5,883, and especially for measuring sheet metal in fig. 5,887.

The method of reading a micrometer caliper to ten-thousandths of an inch is explained in figs. 5,884 to 5,886. Having found the thickness of a sheet of metal in decimal fraction of an inch, the corresponding gauge number is found by consulting the proper gauge table.

Fig. 5,882.—Lufkin spring joint multi-fold boxwood rule particularly designed for taking inside measurements of openings, such as distance between joists in roughing out work, pipe runs under floors and various other similar measurements as are difficult to take with the ordinary folding rule, but serves also as a common rule in ordinary measuring.
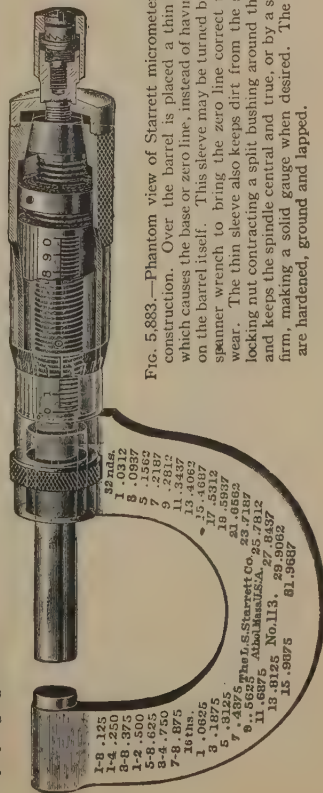
Fig. 5,883.—Phantom view of Starrett micrometer calipers showing construction. Over the barrel is placed a thin graduated sleeve, which causes the base or zero line, instead of having this line marked on the barrel itself. This sleeve may be turned by means of a small spanner wrench to bring the zero line correct to compensate for wear. The thin sleeve also keeps the spindle central and true, or by a slight turn locks it firm, making a solid gauge when desired. The anvil and spindle are hardened, ground and lapped.

32 nds.
1 .0312
3 .0937
5 .1562
7 .2187
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687

1-8 .125
1-4 .250
3-8 .375
1-2 .500
5-8 .625
3-4 .750
7-8 .875
1 .0625
5 .1875
.3125
.4375

5.5625 The I.S.Starrett Co. 23.7187
11.6875 Athol Mass.U.S.A. 25.7812
13.8125 No.113. 27.8437
15.9375 29.9062
31.9687
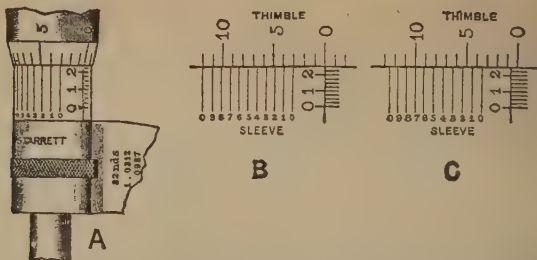
Figs. 5,884 to 5,886.—Vernier micrometer caliper and method of reading. Readings in ten thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier who invented the device in 1631. *As applied* to a caliper this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is therefore one-tenth of a space on the thimble. In the figure B, the third line from 0 on thimble coincides with the first line on the sleeve. The next two lines on thimble and sleeve do not coincide by one-tenth of a space; the next two, marked **5 and 2**, are two-tenths apart, and so on. *In opening* the tool, by turning the thimble to **the left**, each space on the thimble represents an opening of one-thousandth of an inch.
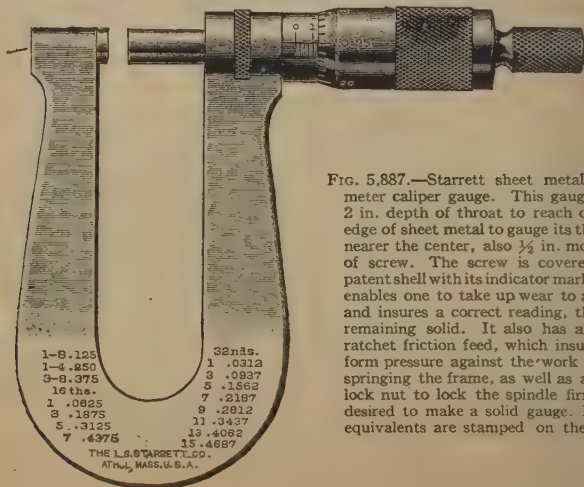
Fig. 5,887.—Starrett sheet metal micrometer caliper gauge. This gauge has a 2 in. depth of throat to reach over the edge of sheet metal to gauge its thickness nearer the center, also ½ in. movement of screw. The screw is covered by a patent shell with its indicator mark, which enables one to take up wear to a nicety and insures a correct reading, the anvil remaining solid. It also has a patent ratchet friction feed, which insures uniform pressure against the work without springing the frame, as well as a patent lock nut to lock the spindle firm when desired to make a solid gauge. Decimal equivalents are stamped on the frame.

Gauge Standards.—The thickness of sheet metal and diameters of wires are indicated usually by gauge numbers called the gauge. Numerous gauges for sheet metal and wire have been in use which leads in many cases to confusion. The principal gauges now in use are given in the accompanying table.

The chief manufacturers at the suggestion of the Bureau of Standards agreed that it would be well to designate the American Steel & Wire Co.'s gauge, which is the same as the Washburn & Moen and the Roebling gauge as the steel wire gauge is used, as its name indicates, for steel wires; it is abbreviated S. W. G., or Stl. W. G. when necessary to distinguish it from S. W. G., the abbreviation for the British standard wire gauge.

The American or Brown & Sharpe wire gauge (A. W. G.) is practically the only gauge used for copper and aluminum wire and for wires in electrical work.

The Birmingham wire gauge (B. W. G.), sometimes called "Stubbs' iron wire gauge", formerly used extensively both in Great Britain and the United States, is now nearly obsolete. It is used chiefly for galvanized iron telegraph wire. The gauge should not be confused with Stubbs' steel wire gauge which has a limited use for tool steel wire and drill rods.

An act of Congress March 3, 1893, legalized a gauge to be used by the custom house departments for sheet iron and sheet steel, the gauge being known as the U. S. standard sheet metal gauge. This gauge is used by about forty-five sheet metal manufacturers.

Gauge Numbers.—The *gauge numbers*, as given in the first column of the table, are for many gauges, *retrogressive*—that is, a larger gauge number denotes a smaller wire, the number of the wire corresponding approximately to the number of

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Figs. 5,884 to 5,886.—*Text Continued.*

If, therefore, the thimble be turned so that the lines marked 5 and 2 coincide the caliper will be opened two-tenths of one-thousandth or two ten-thousandths. Turning the thimble further, until the line 10 coincides with the line 7 on the sleeve as in engraving C, the caliper has been opened seven ten-thousandths, and the reading of the tool is .2507. To read a ten-thousandths caliper, first note the thousandths as in the ordinary caliper, then observe the line on the sleeve which coincides with a line on the thimble. If it be the second line, marked 1, add one ten-thousandth; if the third, marked 2, add two ten-thousandths, etc.

COMPARISON OF WIRE GAUGES

Gauge No.	American or Brown & Sharpe	Birmingham or Stubs	Wash. & Moen	Imperial S. W. G.	London or Old English	United States Standard	Gauge No.
0000000	....	......	.490	.500	......	.500	0000000
000000	.5800	......	.460	.464	......	.46875	000000
00000	.5165	......	.430	.432	......	.4375	00000
0000	.4600	.454	.3938	.400	.454	.40625	0000
000	.4096	.425	.3625	.372	.425	.375	000
00	.3648	.380	.3310	.348	.38	.34375	00
0	.3249	.340	.3065	.324	.34	.3125	0
1	.2893	.300	.2830	.300	.3	.28125	1
2	.2576	.284	.2625	.276	.284	.265625	2
3	.2294	.259	.2437	.252	.259	.25	3
4	.2043	.238	.2253	.232	.238	.234375	4
5	.1819	.220	.2070	.212	.22	.21875	5
6	.1620	.203	.1920	.192	.203	.203125	6
7	.1443	.180	.1770	.176	.18	.1875	7
8	.1285	.165	.1620	.160	.165	.171875	8
9	.1144	.148	.1483	.144	.148	.15625	9
10	.1019	.134	.1350	.128	.134	.140625	10
11	.09074	.120	.1205	.116	.12	.125	11
12	.08081	.109	.1055	.104	.109	.109375	12
13	.07196	.095	.0915	.092	.095	.09375	13
14	.06408	.083	.0800	.080	.083	.078125	14
15	.05707	.072	.0720	.072	.072	.0703125	15
16	.05082	.065	.0625	.064	.065	.0625	16
17	.04526	.058	.0540	.056	.058	.05625	17
18	.04030	.049	.0475	.048	.049	.05	18
19	.03589	.042	.0410	.040	.040	.04375	19
20	.03196	.035	.0348	.036	.035	.0375	20
21	.02846	.032	.03175	.032	.0315	.034375	21
22	.02535	.028	.0286	.028	.0295	.03125	22
23	.02257	.025	.0258	.024	.027	.028125	23
24	.02010	.022	.0230	.022	.025	.025	24
25	.01790	.020	.0204	.020	.023	.021875	25
26	.01594	.018	.0181	.018	.0205	.01875	26
27	.01420	.016	.0173	.0164	.0187	.0171875	27
28	.01264	.014	.0162	.0148	.0165	.015625	28
29	.01126	.013	.0150	.0136	.0155	.0140625	29
30	.01003	.012	.0140	.0124	.01372	.0125	30
31	.008928	.010	.0132	.0116	.0122	.0109375	31
32	.007950	.009	.0128	.0108	.0112	.01015625	32
33	.007080	.008	.0118	.0100	.0102	.009375	33
34	.006305	.007	.0104	.0092	.0095	.00859375	34
35	.005615	.005	.0095	.0084	.009	.0078125	35
36	.005000	.004	.0090	.0076	.0075	.00703125	36
37	.004453	......	.0085	.0068	.0065	.006640625	37
38	.003965	......	.008	.0060	.0057	.00625	38
39	.003531	......	.0075	.0052	.005	....	39
40	.003145	......	.007	.0048	.0045	....	40
41	.002800	......	......	.0044	......	....	41
42	.002494	......	......	.004	......	....	42
43	.002221	......	......	.0036	......	....	43
44	.001978	......	......	.0032	......	....	44
45	.001761	......	......	.0028	......	....	45
46	.001568	......	......	.0024	......	....	46
47	.001397	......	......	.002	......	....	47
48	.001244	......	......	.0016	......	....	48
49	.001018	......	......	.0012	......	....	49
50	.0009863	......	......	.001	......	....	50

drawings to which it has been subjected. The diameters of the wires of successive numbers increase according to a geometrical ratio. The basic sizes are No. 36 wire, which is .005 in. and No. 0000, which is .460 in. in diameter. Between these two sizes there are thirty-eight sizes, each succeeding one being derived from the preceding size by multiplying it by the standard ratio, which is 1.1229322. For practical purposes, this ratio may be assumed as 1.123, hence the diameter of each succeeding number is found by multiplying the diameter of the preceding number by 1.123.

Gauge Plates.—In order to conveniently and quickly measure the size of sheet metal or wire plates, or as they are called

NOTE.—The *American wire gauge* was devised by J. R. Brown, one of the founders of the Brown & Sharpe Mfg. Co., in 1857. It very speedily superseded the Birmingham wire gauge in the United States, which was then in general use. It is perhaps more generally known by the name "Brown & Sharpe Gauge," but this name is not the one preferred by the Brown & Sharpe Mfg. Co. In their catalogues, they regularly refer to the gauge as the "American Standard Wire Gauge." It should not be called *Standard*, since it is not the standard gauge for all metals in the United States; and further, since it is not a legalized gauge, as are the (British) Standard Wire Gauge and the United States Standard Sheet Metal Gauge. This is the only gauge, the successive sizes of which are determined by a simple mathematical law. The American wire gauge has the property in common with a number of other gauges that its sizes represent approximately the successive steps in the process of wire drawing.

NOTE.—*The Steel Wire gauge* was established by Ichabod Washburn about 1830, and was named after the Washburn & Moen Mfg. Co. This company is no longer in existence, having been merged into the American Steel & Wire Co. The latter company continued the use of the Washburn & Moen gauge for steel wire, giving it the name "American Steel & Wire Co.'s Gauge." The company specifies all steel wire by this gauge, and states that it is used for fully 85 per cent of the total production of steel wire. This gauge was also formerly used by the John A. Roebling's Sons Co. who names it the Roebling gauge. However, the Roebling company, who are engaged in the production of wire for electrical purposes, now prefer to use the "American Wire Gauge."

NOTE.—*The Birmingham Wire Gauge* is said to have been introduced early in the eighteenth century, and a table of its diameters is given in Holtzapffel's "Turning" (London, 1846). Its numbers were based upon the reductions of size made in practice by drawing wire from rolled rod; thus, rod, was called No. 0; first drawing No. 1 and so on. Its gradations of size are very irregular. Some of the later gauges were based on the Birmingham.

NOTE.—*In using* the gauges known as Stubbs' gauges, there should be constantly borne in mind the difference between Stubbs' iron wire gauge and Stubbs' steel wire gauge. The Stubbs iron wire gauge is the one commonly known as the English standard wire, or Birmingham gauge, and designates the Stubbs' *soft* wire sizes. The Stubbs steel wire gauge is the one that is used in measuring drawn steel wire or drill rods of Stubbs' make and is also used by many makers of American drill rods.

"gauges" may be obtained having numbered slots or holes into which the sheet metal or wire may be fitted. These gauges which are usually circular or rectangular in shape are shown in figs. 5,888 and 5,889. Obviously they are time

Fig. 5,888.—Starrett gauge plate for sheet metal. *Range* 0 to 36, the gauge numbers are those of the U. S. standard gauge for sheet and plate iron and steel as adopted by Congress March 3, 1893. The decimal equivalent of each gauge number is stamped on the back.

savers as their use avoids setting and reading a micrometer caliper and reference to a gauge table.

Distinction Between Mass and Weight.—These two terms are very frequently confused. By definition: *mass is the quantity of matter contained in a given body,* and *weight,* the

pull of gravity on the body. The mass of a given body remains constant, whereas its weight varies according to *location* of the body, that is, a given body at or near sea level will weigh more than it will if weighed at the top of a mountain.*

Fɪɢ. 5,889.—Starrett gauge plate for wire. *Range* 0 to 36. The gauge numbers of the American standard wire gauge or Brown & Sharpe. The decimal equivalents are stamped on the back.

The weight of a body not only varies with its distance above sea level, but also with its distance north or south of

*NOTE.—If a load of coal should weigh 2,000 pounds at the sea level on a pair of platform scales, and should then be drawn to the top of a mountain a mile high and similarly weighed, the scales would again balance at 2,000 pounds because any variation in the attraction of gravity between the two places would affect the counterpoise of the scales in the same ratio that it affected the body weighed, but if the coal were weighed in a large spring balance, it would be found to weigh only about 1,999 pounds on the mountain top; yet it is perfectly plain that the quantity of matter in the coal would not be altered in any way by the journey.

the equator. Accordingly some standard for weighing is necessary, the accepted standard being *the pull of the earth on the unit pound weight at or near the sea level and at latitude 45°.*

The unit of mass is the quantity of matter contained in a certain piece of platinum accepted as the standard unit. Weight is not the correct measure for mass. The correct
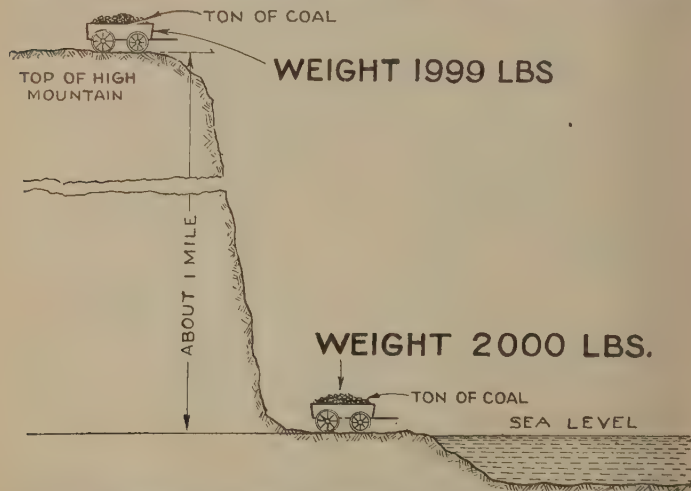

Fig. 5,890.—Weight of a "ton of coal" at sea level and on top of a high mountain, *illustrating* that the weight or pull on a substance due to gravity varies with the elevation. The accepted standard for weight is *the pull per unit of weight due to gravity when the object is at or near sea level and at latitude 45°.*

numerical expression for mass is obtained by dividing its weight as determined by a spring balance by the acceleration *g*, due to gravity at that point. For practical purposes this means the weight as determined by a good spring balance divided by 32.16.

Example.—What is the mass of a sheet of lead weighing 100 lbs.?
$$100 \div 32.16 = 3.11 \text{ lbs. mass.}$$

Unfortunately both weight and mass are by custom expressed in pounds which is ambiguous and sometimes leads to confusion. The mass of a body is considered in the study of motion.

Density.—If equal volumes of different substances as mercury, lead, iron, wood or cork be weighed they will be found to have widely different masses. The term *density* is used in this connection to denote *the mass of unit volume of a substance*.

Thus taking the cu. ft. as unit volume, and the lb. as unit mass, thus one cu. ft. of water is found to weigh 62.3 lbs. The density of water and other liquids and gases is not constant but varies with the temperature. Thus in the case of water its density at various temperatures is as follows:

Weight of Water Per Cu. Ft.

Temperature Fahr..............	32°	39.1°	62°	212°
Weight, lbs.....................	62.42	62.425	62.36	59.76

The density of some well-known substances is given in the following table:

Densities

Substance	Weight per cu. ft.	Weight per cu. in.	Substance	Weight per cu. ft.	Weight per cu. in.
Aluminum...........	166.5	0.0963	Lead...........	709.7	0.4106
Antimony...........	421.6	0.2439	Mercury at60°..	846.8	0.4911
Bismuth............	612.4	0.3544	Nickel.........	548.7	0.3175
Gold, pure..........	1200.9	0.6949	Silver.........	655.1	0.3791
Copper.............	552.	0.3195	Steel..........	489.6	0.2834
Iron, cast............	450.	0.2604	Tin............	458.3	0.2652
Iron, wrought........	480.	0.2779	Zinc...........	436.5	0.2526

Specific Gravity.—By definition, the specific gravity of a body is *the ratio between the weight of a body and the weight of an equal volume of water*. That is,

$$\text{specific gravity} = \frac{\text{weight of body}}{\text{weight of equal volume of water}}$$

Since the density of water varies with the temperature, the
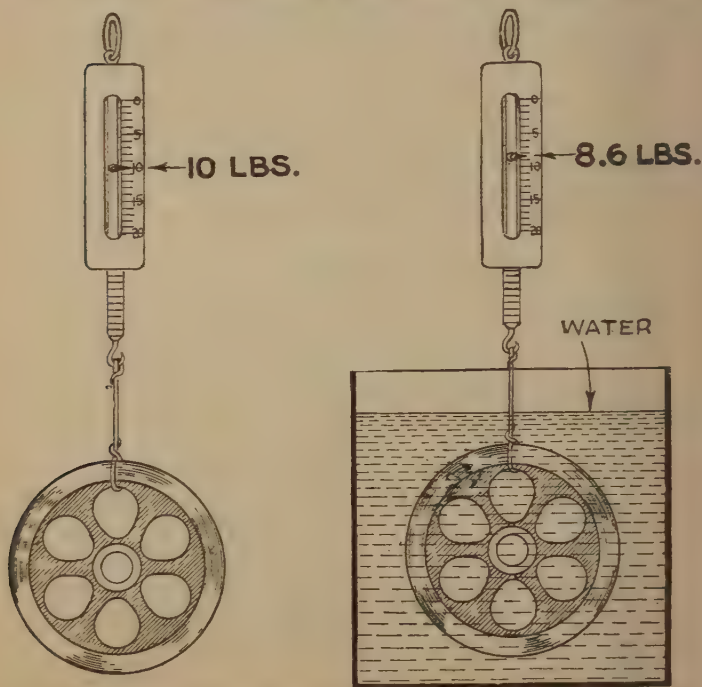
Figs. 5,891 and 5,892.—Specific gravity, 2nd method, by submersion; *object heavier than water*.

standard temperature for the water is 62° Fahr.   There are various methods of finding the specific gravity of a substance depending upon the nature of the substance, whether solid, liquid or gas, heavier or lighter than water, and upon its shape. The following rule covers all the various processes for either solids or liquids, the differences arising from the method of finding the weight of the equal volume of water.

Rule.—1. *Weigh the body.*   **2.** *Find the weight of an equal volume of water.*   **3.** *Divide the weight of the body by the weight of the equal volume of water.*

1st *method—calculation.*

Example.—A lead keel for a sail boat 3 x 6 ins. cross section and 8 ft. long.   What is its specific gravity?

First the keel is weighed and found to weigh 709.7 lbs.   By calculation

$$\text{vol. of keel} = \frac{3 \times 6}{144} \times 8 = 1 \text{ cu. ft.}$$

weight of 1 cu. ft. of water at 62° Fahr. = 62.36 lbs.

specific gravity of keel = 707.9 ÷ 62.36 = 11.35

2nd *method—submersion* (*object heavier than water*).

Example.—If a certain iron casting weighs 10 lbs. in air and 8.6 lbs. when submerged in water, what is its specific gravity?

Loss of weight in water = 10 − 8.6 = 1.4 lbs.

$$\text{specific gravity} = \frac{\text{weight in air}}{\text{loss of weight in water}} = \frac{10}{1.4} = 7.14$$

3rd *method—submersion* (*object lighter than water*).

Example.—If a piece of wood weigh 12 lbs. in air and with a suitable sinker attached, the combination weighs 27 lbs. with sinker submerged under water, and 9 lbs. when both are submerged.   What is the specific gravity of the wood?

The *lifting effect* of the water on the wood is
27 − 9 = 18 lbs.

←12 LBS.

←27 LBS.

9 LBS.

WOOD

WOOD AND
SINKER
SUBMERGED

SINKER
SUBMERGED
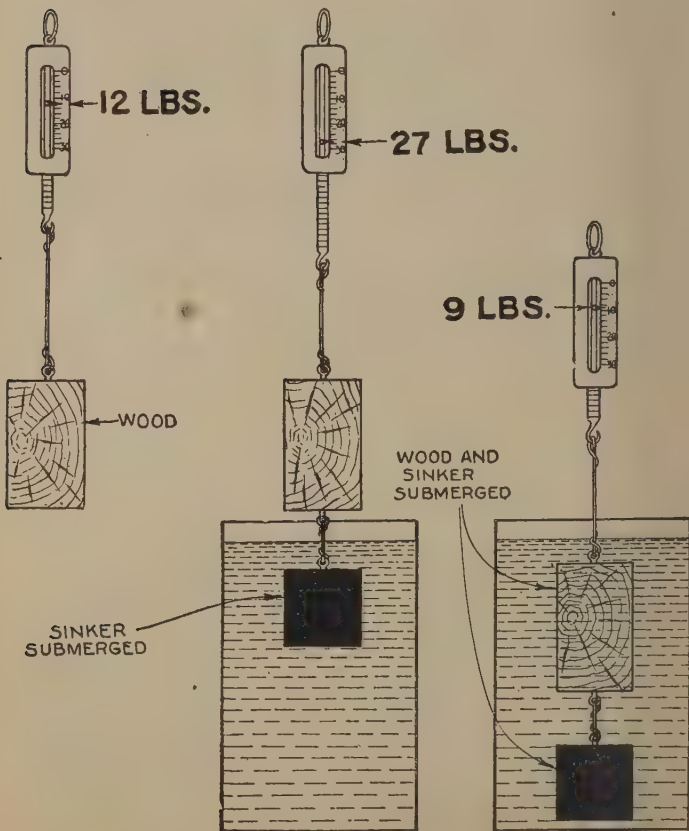
FIGS. 5,893 to 5,895.—Specific gravity, 3rd method, by submersion; *object lighter than water*

$$\text{specific gravity} = \frac{\text{weight of wood}}{\text{lifting effect}} = \frac{12}{18} = .667$$

4th method—hydrometer test.

The specific gravity of liquid is ordinarily determined by the hydrometer which consists of a glass bulb with graduated stem and weighted with shot to make it float upright.

The graduations consist of a paper scale enclosed inside the stem so
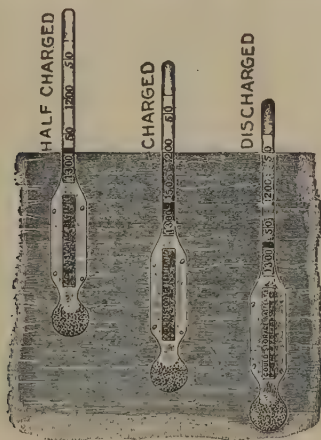
FIG. 5,896.—Specific gravity of liquids by hydrometry, illustrating method of ascertaining state of charge of a storage battery as indicated by hydrometer reading of specific gravity of electrolyte.

graduated that the specific gravity can be read directly. In light liquids like gasoline, alcohol, kerosene, etc., the hydrometer must sink deeper to displace its weight of liquid than in heavy liquids like brine and acids.

It is usual to have two hydrometers: one for heavy liquids on which the mark 1.000 for water is near the top, and one for light liquids. on which the mark 1.000 is near the bottom of the stem.

The most common everyday use of the hydrometer is for testing the

specific gravity of the electrolyte in storage batteries as an indication of the amount of charge in the battery. This test is shown in fig. 5,896.

Water.—This remarkable substance is a *compound of hydrogen and oxygen in the proportion of 2 parts by weight of hydrogen to 16 parts by weight of oxygen*.

Since the atom of oxygen is believed to weigh 16 times as much as the
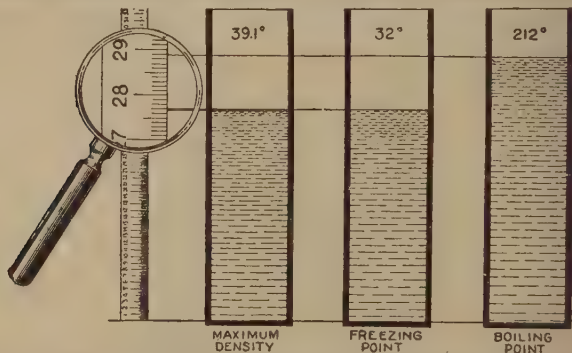
Figs. 5,897 to 5,899 —The most remarkable characteristic of water: *expansion below and above its temperature or "point of maximum density" 39.1° Fahr.* Imagine one pound of water at 39.1° F. placed in a cylinder having a cross sectional area of 1 sq. in. as in fig. 5,897. The water having a volume of 27.68 cu. ins., will fill the cylinder to a height of 27.68 ins. If the liquid be cooled it will expand, and at say the *freezing point* 32° F., will rise in the tube to a height of 27.7 ins., as in fig. 5,898, before freezing. Again, if the liquid in fig. 5,898 be heated, it will also expand and rise in the tube, and at say the *boiling point* (for atmospheric pressure 212° F.), will occupy the tube to a height of 28.88 cu. ins. as in fig. 5,899.

atom of hydrogen, the molecule of water is said to contain 2 atoms of hydrogen and 1 atom of oxygen, being represented by the formula H_2O.

Under the influence of temperature and pressure this substance H_2O may exist as

1. A solid;
2. A liquid, or
3. A gas.

NOTE.—*The bottle method* of obtaining the specific gravity of liquids is a method of precision as used in the laboratory.
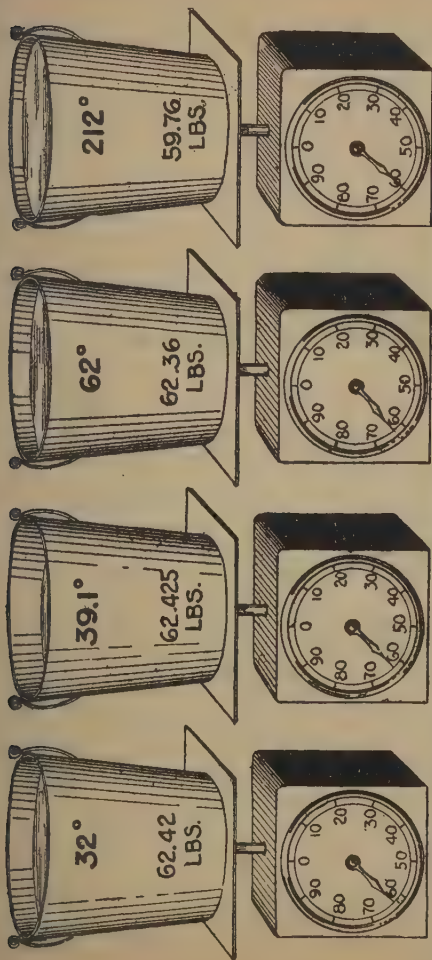
FIGS. 5,900 to 5,903.—Pail containing a cu. ft. of water weighed at various temperatures, illustrating the effect of temperature on the density of the water.

As a solid it is called *ice**; as a liquid, *water*, and as a gas, *steam*.

Water at its maximum density (39.1 degrees F.) will expand as heat is added, and it will also expand slightly as the temperature falls from this point, as illustrated in figs. 5,897 to 5,899.

Water will freeze at 32° Fahr. and boil at 212°, when the barometer reads 29.921 inches.†

*NOTE.—*Compressibility of water.*—Water is very slightly compressible. Its compressibility is from .00004 to 000051 for one atmosphere, decreasing with increase of temperature. For each foot of pressure, distilled water will be diminished in volume .0000015 to .0000013. Water is so slightly compressible that even at a depth of a mile a cubic foot of water will weigh only about ½ lb. more than at the surface.— *Kent.*

†NOTE.—29.921 inches of mercury = standard atmosphere = 14,969 lbs. per sq. in.

The boiling point of water is not the same in all places. It decreases as the altitude increases; at an altitude of 5,000 ft. water will boil at a temperature of 202° Fahr.

An increase of pressure will elevate the boiling point of water. At maximum density the weight of a cu. ft. is generally taken at the figure given by Rankine, 62.425 lbs.*

One U. S. gallon (231 cu. ins.) of water weighs 8⅓ lbs.

The figure 8⅓ is correct when the water is at a temperature of 65° Fahr.
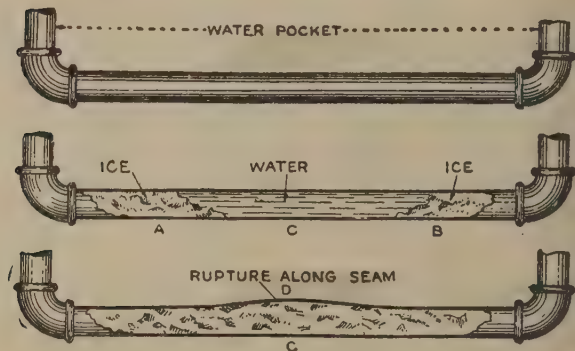
Figs. 5,904 to 5,906.—The bursting of pipes during freezing weather, illustrating the effect of pressure upon the freezing point. In draining pipes exposed to prevent freezing, care should be taken to remove all the water out of any water pockets that may exist, such as shown in fig. 42. Assuming the pocket illustrated in fig. 5,905 to be full of water in freezing weather, it sometimes happens that the water at A and B, will freeze before it does at C, thus forming two slugs of ice enclosing the water C When C, freezes, there being no room for expansion, the pipe bursts as indicated at D. *The popular impression* that pipes will burst at or very little below 32° Fahr., is erroneous. In fact the enormous pressure required to burst so called wrought iron pipe is not generally known, nor the effect of the pressure on the freezing point. For instance, the average bursting pressure of one-half inch standard pipe is 14,000 lbs., or 911.5 atmospheres per sq. in. and since the freezing point is lowered .0133° Fahr. for each additional atmosphere, the freezing point required to burst oe-half inch pipe is 32—(911.5×.0133) =20 Fahr ; that is to say, it would require a temperature of 20° to burst a one-half inch pipe of average strength by freezing.

---

*NOTE.—One cu. ft. of ice at 32° Fahr., weighs 57.5 lbs.; one lb. of ice at 32° F. has a volume of .0174 cu. ft., or 30 067 cu. ins. The relative volume of ice to water at 32° F., is 1.0855, the expansion in passing into the solid state being 5.55%. Specific gravity of ice = .922, water at 62° F. being 1 —*Clark.*

The pressure of water varies with the *head*, and is equal to .43302 lbs. per sq. in. for every foot of (static) head.

Heat.—By definition heat *is a form of energy known by its effects*.

These effects are indicated through the touch and feeling, as well as by the expansion, fusion, combustion or evaporation of the matter upon which it acts.

Temperature is that which indicates how hot or cold a substance is; a measure of *sensible heat*.

FIG. 5,907.—Method of judging the heat of a soldering bit or so called "iron," illustrating *sensible heat*.

Sensible heat is that heat which produces a rise of temperature as distinguished from *latent heat*.

Latent heat is that quantity of heat required to change the *state* or condition under which a substance exists without changing its temperature.

Thus a definite quantity of heat must be transferred to ice at 32° to change it into water at the same temperature.

Specific heat is the ratio of the quantity of heat required to raise the temperature of a given weight of any substance one degree to the quantity of heat required to raise the temperature of the same weight of water from 62° to 63° Fahr.

When bodies of unequal temperatures are placed near each other, heat leaves the hot body and is absorbed by the colder body until the temperature of each is equal. This is called a transfer of heat.

The rate by which the heat is absorbed by the colder body is proportional

Figs. 5,908 and 5,910.—Three ways in which heat is transferred; fig. 5,908, by radiation; fig. 5,909, by conduction; fig. 5,910, by convection. In fig. 5,908, the water in the beaker is heated by *heat rays which radiate in straight lines in all directions from the flame*. In fig. 5,909, the flame will not pass through the wire gauze, because the latter conducts the heat away from the flame so rapidly that the gas on the other side is not raised to the temperature of ignition. In fig. 5,910, the water nearest the flame becomes heated and expanded. It is then rendered less dense than the surrounding water, and hence rises to the top while the colder and therefore denser water from the sides flows to the bottom thus *transferring heat by convection currents*.

to the difference of temperature between the two bodies. The greater the difference of temperature, the greater the rate of flow of the heat.

The transfer of heat takes place by radiation, conduction or convection.

Thus, in a boiler, heat is given off from the furnace fire in rays which radiate in straight lines in all directions being transferred to the crown and sides of the furnace by radiation; it passes through the plates by conduction, and is transferred to the water by convection, that is, by currents.

Bodies expand by the action of heat. For instance, boiler plates are riveted with red hot rivets in an expanded state;
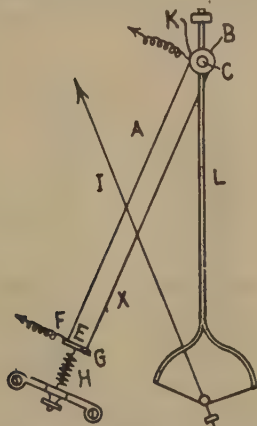

FIG. 5,911.—Diagram showing principle and construction of the Whitney hot wire instruments illustrating *expansion by the action of heat.* The action of instruments of this type depends on the heating of a wire by the passage of a current of electricity causing the wire to lengthen. This elongation is magnified by suitable mechanism and transmitted to the pointer of the instrument.

on cooling the rivets contract and draw the plates together with great force making a tight joint.

An exception to the rule, it should be noted, is water, which contracts as it is heated from the freezing point 32° Fahr., to the point of maximum density 39.1°; at other temperatures it expands.

Heat and Work.—Heat develops *mechanical force* and *motion*, hence it is *convertible into mechanical work.*

Heat is measured by a standard unit called the British unit of heat.

The British thermal unit is equal to $1/180$ part of the heat required to raise the temperature of one pound of water from 32° to 212° Fahr.*†

It should be noted that this is the definition adopted in this work for the British thermal unit (*B.t.u.*), corresponding to the unit used in the Marks and Davis steam tables, which is now the recognized standard.
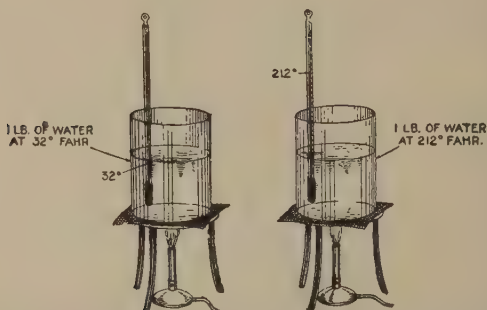
FIGS. 5,912 and 5,913.—Experiment illustrating the British thermal unit. Place one pound of water at 32° Fahr. into a beaker over a Bunsen burner as in fig. 5,912 assuming no loss of heat from the water. It will, according to the definition, require 180 heat units to heat the water from 32° to 212° Fahr. Now, if the transfer of heat take place at a uniform rate and it require, say five minutes to heat the water to 212°, then one heat unit will be transferred to the water in $(5 \times 60) \div 180 = 2$ seconds.

Work.—By definition work is *the overcoming of resistance through a certain distance by the expenditure of* **energy.**

Work is measured by a standard unit called the *foot pound.*

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*NOTE.—The old definition of the heat-unit (*Rankine*), viz., the quantity of heat required to raise the temperature of 1 lb. of water 1° Fahr., at or near its temperature of maximum density (39.1° F.) was the standard till 1909.

†NOTE.—By Peabody's definition, the heat required to raise 1 lb. of water from 32° to 212° is 180.3 instead of 180 units, and the latent heat at 212° is 969.7 instead of 970.4.

A foot pound is *the amount of work done in raising one pound one foot*, or in overcoming a pressure of one pound through a distance of one foot.

Thus, if a 5 pound weight be raised 10 feet, the work done is $5 \times 10 = 50$ foot pounds.

Joule's Experiment.—It was shown by experiments made by Joule (1843–50) that 1 *unit of heat* = 772 *units of work*. This
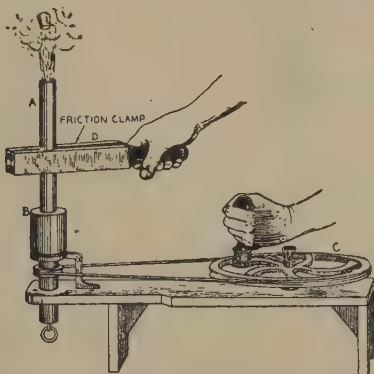

Fig. 5,914.—Experiment showing relation between heat and work. Take a brass tube A,B, attached to a spindle geared to rotate rapidly and partly fill the tube with water and insert a cork. Apply a friction clamp D, and rapidly rotate the tube by turning the wheel C. The energy expended in overcoming the friction due to the clamp and rotating the tube causes the water to heat and finally boil; if continued long enough, the pressure generated will expel the cork. During the operation *work has been transformed into heat.*

is known as the "mechanical equivalent of heat" or Joule's equivalent.

More recent experiments by Prof. Rowland (1880) and others give higher figures; 778 is generally accepted, but 777.5 is probably more nearly correct, the value 777.52 being used by Marks and Davis in their steam tables.

The value 778 is sufficiently accurate for ordinary calculations.

Energy.—By definition, *energy is stored work*, that is, the ability to do work, or in other words, to move against resistance.

A body may possess energy whether it do any work or not, but no work is ever done except by the expenditure of energy. There are two kinds of energy:

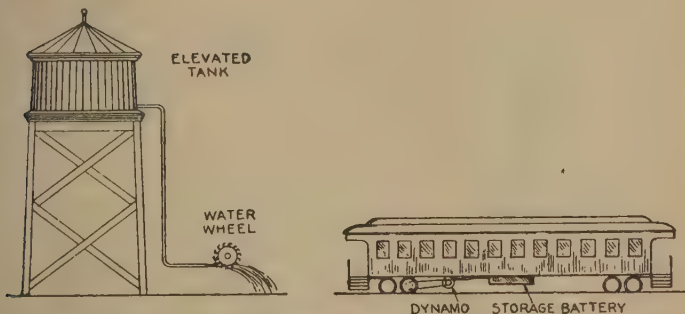1. *Potential energy.*
2. *Kinetic energy.*
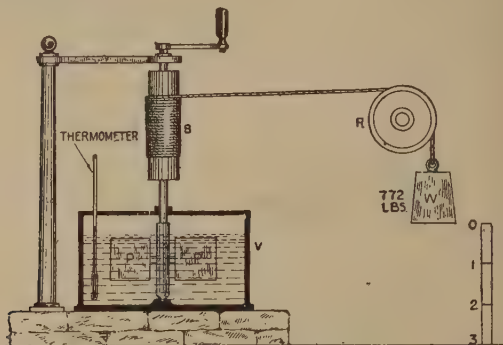
FIG. 5,915.—The mechanical equivalent of heat. *In 1843, Dr. Joule* of Manchester, England, performed his classic experiment, which revealed to the world the mechanical equivalent of heat. As shown a weight W, is attached to a cord which passes over a pulley R, and is wound around a revolving drum B. Attached to the drum is a spindle having fastened at its lower end vanes or paddles P,P', made of thin pieces of sheet metal. These paddles are immersed in a vessel V, containing a definite quantity of water, and made to revolve with as little friction as possible in a vessel containing a pound of water whose temperature was known. The paddle was actuated by a known weight falling through a known distance. *A pound falling through a distance of one foot represents a foot pound of work.* At the beginning of the experiment a thermometer was placed in the water, and the temperature noted. The paddle was made to revolve by the falling weight. When 772 foot pounds of energy had been expended on the pound of water, the temperature of the latter had risen one degree, and the relationship between heat and mechanical work was found; the value 772 foot pounds is known as Joule's equivalent. More recent experiments give higher figures, the value 778, is now generally used but according to Kent 777.62 is probably more nearly correct. *Marks and Davis* in their steam tables have used the figure 777.52.

Potential energy is *energy due to position*, as represented, for instance, by a body of water stored in an elevated reservoir, capable of doing work by means of a water wheel.

Kinetic energy is *energy due to momentum*, that is to say, the energy of a moving body.

Conservation of Energy.—The doctrine of physics, that energy can be transmitted from one body to another or transformed in its manifestations, but *may neither be created nor destroyed*.

Power.—By definition, power is *the* **rate** *at which work is done;* in other words, it is *work divided by the* **time** *in which it is done*.

Figs. 5,916 and 5,917.—Potential and kinetic energy. In fig. 5,916, the water stored in the elevated tank possesses energy by virtue of its position; being higher than the water wheel, the water will flow by gravity through the pipe and do work on the wheel. Thus, the potential energy of the water at rest in the tank is, when it flows through the pipe converted into kinetic energy which is spent on the wheel. Fig. 5,917 represents a railway car with axle lighting system. If the car be set in motion and then no further power be applied its momentum or kinetic energy will drive the dynamo which in turn will charge the storage battery, and acting like a brake will gradually bring the car to rest. During this operation, the kinetic energy, originally possessed by the moving car, is absorbed by the dynamo (neglecting friction) and delivered to the battery as electrical energy which may be used in lighting the car.

The unit of power in general use is the **horse power*** which is defined as 33,000 *foot pounds per minute*.

That is, one horse power is required to raise a weight of

33,000 pounds   1 foot in one minute

*NOTE.—The term "horse power" is due to James Watt, who figured it to represent the power of a strong London draught horse to do work during a short interval, and used it as a power rating for his engines.

   3,300 pounds   10 feet in one minute
           330 pounds   100 feet in one minute
            33 pounds   1,000 feet in one minute
           3.3 pounds 10,000 feet in one minute
             1 pound 33,000 feet in one minute, etc.

Pressure.—By definition, pressure is *a force, of the nature*
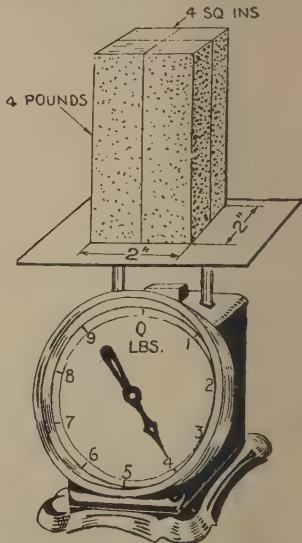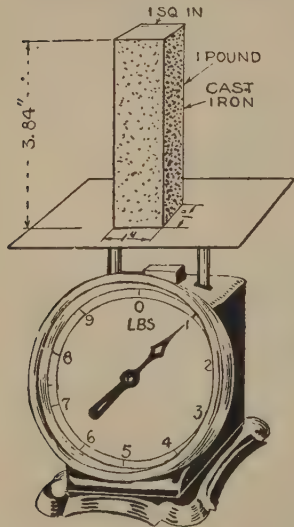
FIGS. 5,918 and 5,919.—*Pressure per square inch.* Cast iron weighs .26 lbs. per cu. in.; hence, a piece 1 ÷ .26 = 3.84 ins. long will weigh one pound. Place this on a scale as in fig. 5,918 and the pointer will register one pound. There is then in this case a pressure of one pound *distributed over a surface of* 1″ × 1″ = 1 sq. in. Now take 4 pieces of iron as in fig. 5,919 and place them on the scale. The pointer will register 4 lbs., indicating a total pressure of 4 lbs. on the scale, but since this pressure is distributed over an area of 2″ × 2″ = 4 sq. ins., it represents a pressure of 4 lbs. ÷ 4 sq. ins. = 1 *pound per square inch.*

of a thrust, distributed over a surface; in other words, the kind
of force with which a body tends to expand, or resists an effort
to compress it.
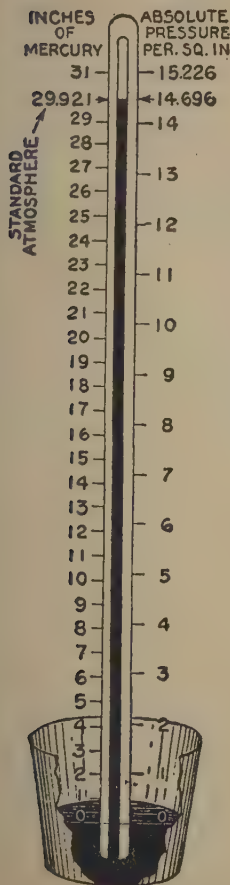
Pressure is usually stated in *pounds per square inch*, meaning that a pressure of a given number of pounds is distributed over each square inch of surface. This should be very clearly understood as further explained in figs. 5,918 and 5,919.

Atmospheric pressure is the force exerted by the weight of the atmosphere on every point with which it is in contact.

At sea level this pressure is for ordinary calculations taken at 14.7 pound per sq. in., and roughly, 15 lbs. per sq. in.

We do not feel the atmospheric pressure because air presses the body both externally and internally so that the pressures in different directions balance.

Atmospheric pressure varies with the elevation. The pressure decreases approximately one-half pound for every 1,000 feet of ascent. It is measured by an instrument called the *barometer*.

Barometer.—By definition a barometer is an instrument for measuring the pressure of the atmosphere, as shown in fig. 5,920. The instrument consists of a glass tube 33 to 34 inches

FIG. 5,920.—Mercurial barometer illustrating the relation between *"inches of mercury"* and absolute pressure in lbs. per sq. in.

high, sealed at the top, filled with pure mercury and inverted in an open cup of mercury. A graduated scale on the instrument permits observations of the fluctuations in the height of the mercurial column, which is highest when the atmosphere is dry, weighing more then than when saturated with aqueous vapor, which is lighter than air. The height of barometric measurement is about 30 inches.

The column of mercury remains suspended at this height

Fig. 5,921.—Elementary boiler or closed vessel illustrating the difference between *gauge*, and *absolute pressure*.

because the weight of a column of mercury 30 inches high is the same as the weight of a like column of air about 50 miles high.

Pressure Scales.—The term vacuum strictly speaking is defined as *a space devoid of matter*. This is equivalent to saying *a space in which the pressure is zero*. According to common

usage it means *any space in which the pressure is less than that of the atmosphere.* This gives rise to two scales of pressure:

1. Gauge pressure.
2. Absolute pressure.

When the hand of a steam gauge is at zero, the pressure actually existing is 14.74 lbs. (referred to a 30 inch barometer) or that of the atmosphere. The scale in the gauge is not marked at this point 14.74 lbs. but zero because in the steam boiler as well as any other vessel under pressure, the important measurement is the difference of pressure between the inside and outside. This difference of pressure or effective pressure for doing work is called the "gauge pressure" because it is measured by the gauge on the boiler.

The second pressure scale is known as *absolute pressure*, because it gives the actual *pressure above zero.* In all calculations relative to the expansion of steam the absolute pressure scale must be used.

Gauge pressure is expressed as absolute pressure by adding 14.74, or for ordinary calaculations, 14.7 lbs.

Thus 80 lbs. gauge pressure = 80 + 14.74 = 94.74 lbs. absolute pressure.

Absolute pressure is expressed as gauge pressure by subtracting 14.7.

Thus 90 lbs. absolute pressure = 90 − 14.7 = 75.3 lbs. gauge pressure.

The pressures below atmospheric pressure are usually expressed in lbs. per sq. in. when making calculations or "inches of mercury" in practice.

Thus, in the engine room, the expression "28 inch vacuum" would signify an absolute pressure in the condenser of .946 lb. per sq. in. absolute, that is to say, the mercury in a mercury column connected to a condenser having a 28 in. vacuum, would rise to a height of 28 ins.

representing the difference between the pressure of the atmosphere and the pressure in the condenser or

$$14.73 - .946 = 13.784 \text{ lbs.}$$

referred to a 30 in. barometer.

Pressure in lbs. per sq. in. is obtained from the barometer reading by multiplying by .49116.

Thus, a 30 inch barometer reading signifies a pressure of

$$.49116 \times 30 = 14.74 \text{ lbs. per sq. in.}$$

The following table gives the pressure of the atmosphere in pounds per square inch for various readings of the barometer.

Pressure of the atmosphere per square inch for various readings of the barometer:

Rule.—*Barometer in inches of mercury* $\times$ *.49116 = lbs. per sq. in.*

Barometer (ins. of mercury)	Pressure per sq. ins., lbs.	Barometer (ins. of mercury)	Pressure per sq. ins., lbs.
28.00	13.75	**29.921**	**14.696**
28.25	13.88	30.00	14.74
28.50	14.00	30.25	14.86
28.75	14.12	30.50	14.98
29.00	14.24	30.75	15.10
29.25	14.37	31.00	15.23
29.50	14.49		
29.75	14.61		

The above table is based on the standard atmosphere, which by definition = **29.921** ins. of mercury = **14.696** lbs. per sq. in., that is **1** in. of mercury = $14.696 \div 29.921 = $ **.49116** lbs. per sq. in.

Thermometer.—This term is generally applied to a glass tube, terminating in a bulb, which is charged with a liquid, usually mercury or colored alcohol. The liquid contracts or expands with changes of temperature, falling or rising in the tube against which is placed a graduated scale.

The common scale is Fahrenheit's, in which zero is the temperature of a mixture of salt and snow; 32° that of melting ice, and 212° that of boiling water. The Celsius and Reaumur scales from the temperature of melting ice to that of boiling
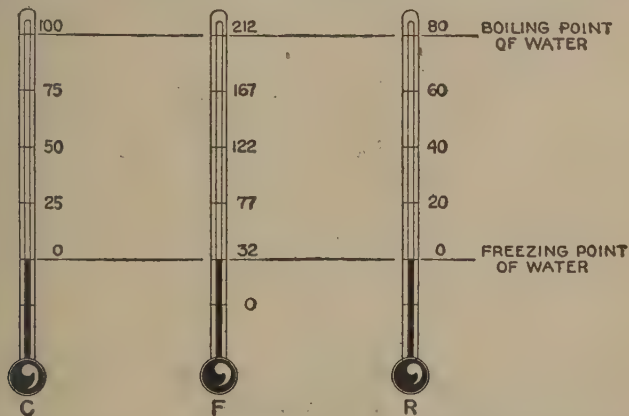
FIGS. 5,922 to 5,924.—Various thermometer scales. Fig. 5,922, Centigrade; fig. 5,923, Fahrenheit; fig. 5,924, Reaumur. From the figures the scales may be clearly compared, and degrees converted from one scale to another without calculation

NOTE.—*Absolute temperature.*—This is defined as *the actual temperature of anything reckoned from absolute zero.* It is taken as the temperature indicated by the thermometer or similar instrument, to which is added 273.1° centigrade or 459.6° Fahrenheit, the difference between absolute zero and the zeros of the respective thermometric scales, which are arbitrarily fixed.

NOTE.—*Absolute zero.*—In physics, temperature or the heat which it represents is regarded as a manifestation of molecular activity in any substance, the higher the temperature, the greater the motion or vibration among the molecules of which every solid, liquid or gaseous body is composed. Experiments have demonstrated that a gas expands when at the freezing point and under constant pressure about $\frac{1}{491.6}$ of its volume for each increase of 1° Fahr. in pressure. This tends to show, that at some point about 491.6° −32° or 459.6° below zero or Fahrenheit's scale, the volume of the gas would have become zero or it would have lost all the molecular vibration which manifests itself as heat. The temperature of this *absolute zero point*, from which all temperatures of gases are reckoned, is estimated at—273.1° C. or −459.6° F. The lowest temperatures yet obtained by anyone are those at which *hydrogen* liquifies, −423° F., and its freezing point, 430.6° F.

water, have 100 graduations and 80 graduations respectively, hence, the Celsius is called the Centigrade thermometer.

The latent heat varies with the boiling point, that is, it decreases as the pressure rises.

30 IN VACUUM
PLUS PRESSURE DUE TO AIR

(30 IN BAROMETER)
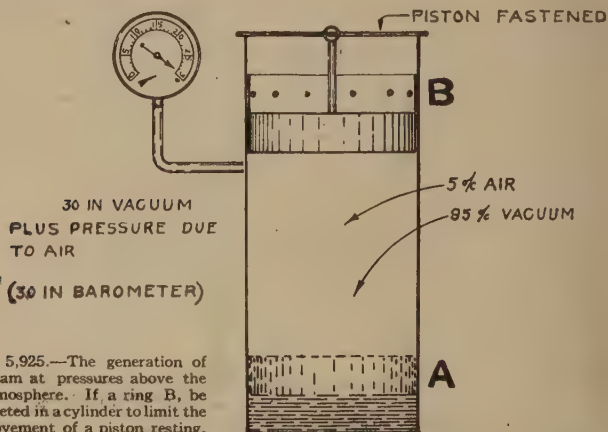
Fig. 5,925.—The generation of steam at pressures above the atmosphere. If a ring B, be riveted in a cylinder to limit the movement of a piston resting, at the beginning of the experi-
ment, on top of a small quantity of water (as indicated by dotted lines A,) and heat be applied, the piston (assumed to have no weight) will rise as steam is formed at atmospheric pressure until it comes in contact with the ring B. Additional heat will cause the pressure of the steam to increase in a definite rate corresponding to the temperature until all the water is evaporated, the cylinder being now filled with *saturated steam*. The pressure of this saturated steam will depend on the relation between its volume and the volume of water from which it was generated. If more heat be now added, the temperature of the steam will increase above that due to its pressure, and the steam becomes *superheated*. Removing the heat supply, the temperature of the gas will gradually diminish, and it loses its superheat and returns to the saturated condition, at which point condensation begins, the pressure and temperature during these changes gradually falling. Condensation continuing until all the steam has condensed, the piston returning to its initial position A. If, during the cooling process, the piston be fastened at the ring B, the pressure of the steam will become less than the atmospheric pressure outside when the temperature falls below 212° Fahr., forming a so called vacuum. The degree of vacuum now increases, or in other words, the pressure under the cylinder or *absolute pressure* becomes less and less until, when all the steam is condensed, it becomes approximately zero, or 14.72 lbs. lower than the pressure of the atmosphere or *gauge pressure* (assuming the barometer reads 30 inches). The pressure remains a little above zero because of the small percentage of air originally contained in the water, which does not recombine with it when the steam condenses, that is, a *perfect vacuum* is not formed *because of this air*, necessitating, in the case of condensing engines, an air or so called vacuum pump.

Steam.—By definition *steam is the vapor of water; the hot invisible vapor given off by water at its boiling point, the latter depending upon the pressure.*

The visible white vapor popularly known as steam is not steam, but a collection of fine watery particles, formed by the condensation of steam.
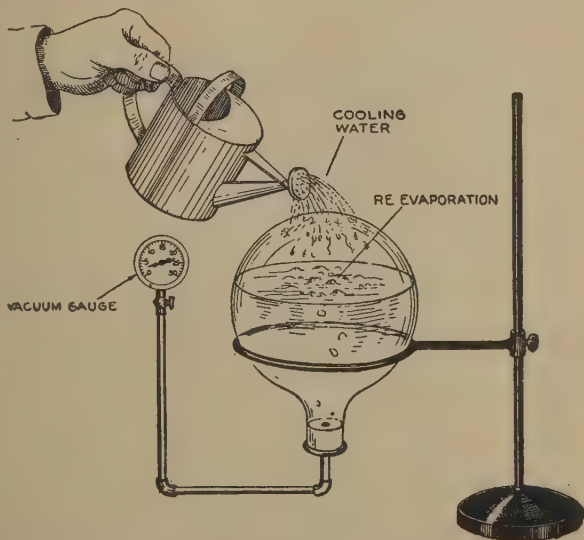

Fig. 5,926.—Lowering the boiling point by diminishing the pressure. Fill a round bottomed flask with water and boil. After it has boiled some time, until the air has been drawn out of the flask by the steam, insert a rubber stopper, having fitted to it a connection leading to a vacuum gauge and invert the flask as shown. The vacuum gauge will now read zero. Now, if some cold water be poured over the flask, the temperature will fall rapidly and some of the steam will condense, thus lowering the pressure within the flask, that is, the vacuum gauge will read 5 or 10 inches indicating a vacuum. The reduced pressure disturbs the equilibrium between pressure and temperature and the water will boil until equilibrium is again restored. The operation may be repeated several times without reheating, the pressure gradually falling each time. At the city of Quito, Ecuador, water boils at 194° Fahr., and on the top of Mt. Blanc at 183°. Again, in a steam boiler in which the pressure is 200 lbs., the boiling point is 387.7°.

Steam is said to be

1. Saturated when its temperature corresponds to its pressure.

2. Superheated when its temperature is above that due to its pressure.

3. Gaseous steam or steam gas when it is highly superheated.
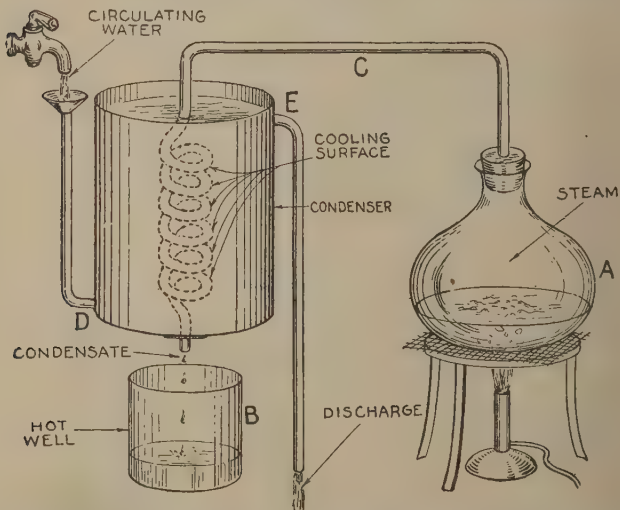
Fig. 5,927.—The condensation of steam. If water be boiled in a flask A, and the steam thus produced led off through pipe C, having a coiled section surrounded by cold water, it will here be cooled below the boiling point and will therefore condense, the *condensate* passing out into the receptacle B, as water. The cooling or "circulating" water enters the condenser at the lowest point D, and leaving at the highest point E.

4. Dry when it contains no moisture. It may be either saturated or superheated.

5. Wet when it contains intermingled mist or spray, its temperature corresponding to its pressure.

Steam exists when there is the proper relation between the temperature of the water and the external pressure. For instance, for a given temperature of the water there is a certain external pressure above which steam will not form. Steam is produced by heating water until it reaches the *boiling point*.

The latent heat of steam is the amount of heat required to change one pound of water into steam of the same temperature.

FIG. 5,928.—*The phenomena of vaporization.* When heat is applied to water in a vessel as shown, it is conducted through the heating surface to the lower state which gradually becomes heated to the boiling point. This is followed by the formation of globules of steam on the heating surface indicating that particles of the water have received a supply of heat equal to the sensible and latent heat of steam at the pressure existing at the bottom of the vessel, thus a *change of state* has taken place, and this may be called *initial vaporization* as distinguished from vaporization or the completion of the process. As more heat is added, more of the water adjacent to the globules is converted into steam which causes the globules to increase in size until their buoyancy becomes sufficient to overcome the tension with the heating surface and *initial disengagement* takes place. Following the course of a globule disengaging from the central and hottest portion of the heating surface, it rapidly rises to the surface and expands as it rises because the pressure gradually decreases due to diminishing head of water. On reaching the *disengaging surface*, a bubble is formed which at once bursts as the water closes in behind the steam contained in the bubble, thus completing the process of vaporization of the original particles of water; that is to say, a *change of state* has taken place and the steam has been disengaged from the water.

Thus, if heat be applied to a pound of pure water having a temperature of 212 degrees F., steam will be formed and in a short time all the water will be evaporated; now if the temperature of the steam so formed be taken, the thermometer will register the same as the boiling water, 212 degrees. It has been accurately determined by experiment that 970.4 degrees of heat, or heat units, must be applied to a pound of boiling water to change it into steam of the same temperature, and this heat is called the latent heat of steam.

Mechanical Powers.—By definition the mechanical powers are *mechanical contrivances that enter into the composition or formation of all machines*.

They are:

1. The lever.
2. The wheel and axle.
3. The pulley.
4. The inclined plane.
5. The screw.
6. The wedge.

These can in turn be reduced to three classes:

1. A solid body turning on an axis.
2. A flexible cord.

NOTE.—*The fusion of ice;* illustrating the **work done when a pound of ice** at 32° *Fahr. is melted or converted into water at the same temperature.* The latent heat of fusion being 143.57 heat units, and since one heat unit is equivalent to 778 ft. lbs., the work done during the fusion of one pound of ice is $778 \times 143.57 = 111,698$ ft. lbs. This is approximately equivalent to the work done when a hoisting engine hoists 2,000 lbs. a distance of 55.8 ft.

NOTE.—The various states of steam as exemplified in the operation of a safety valve. By closely observing a safety valve when blowing off, as for instance the safety valve on a locomotive, or better the safety valve on a marine boiler, furnishing superheated steam, very interesting phenomena can be observed. Very close to valve the escaping gas is entirely invisible being at this point super-heated. Further away, the outline of the ascending column is seen, the interior being invisible and gradually becoming "foggy" and as the vapor ascends, denoting the gradual reduction in temperature, the steam becoming saturated and supersaturated or wet, reaching the white state a little further away, where it is popularly and erroneously known as "steam." *Steam is invisible.* The reason the so called wet steam can be seen is because wet steam is a mechanical mixture made up of saturated steam which is invisible, and which holds in suspension a multiplicity of fine water globules formed by condensation; it is the collection of water globules or *condensate* that is visible.

3. A hard and smooth inclined surface.

For the mechanism of the wheel and axle and of the pulley, merely combines the principle of *the lever* with the tension of the cords; the properties of the screw depend entirely on those of the lever and the inclined plane; and the case of the wedge is analogous to that of a body sustained between two inclined planes.

They all depend for their action upon what is known as the *principle of work*, one of the important principles in mechanics and in the study of machine elements.

The principle of work states that, neglecting frictional or other losses *the applied force, multiplied by the distance through which it moves, equals the resistance overcome, multiplied by the distance through which it is overcome.* That is, a force acting through a given distance, can be made to overcome a greater force acting as a resistance through a less distance; but no possible arrangement can be made to overcome a greater force through the same distance. The principle of work may be also stated as follows:

Work put into machine = lost work + work done by machine.

The principle holds true in every case. It applies equally to a simple level, the most complex mechanism, or to a so-called "perpetual motion" machine. No machine can be made to perform work unless a somewhat greater amount—enough to make up for the losses—be applied by some external agent. As in the "perpetual motion" machine no such outside force is supposed to be applied, this problem is impossible, and against all the laws of mechanics.

The Lever.—It consists of an inflexible bar or rod, some point of which being supported, the rod itself is movable freely about that point as a center of motion.

In the lever three points are to be considered, viz.: the *fulcrum* or point about which the lever turns, the point where the force is applied, and the point where the weight is applied.
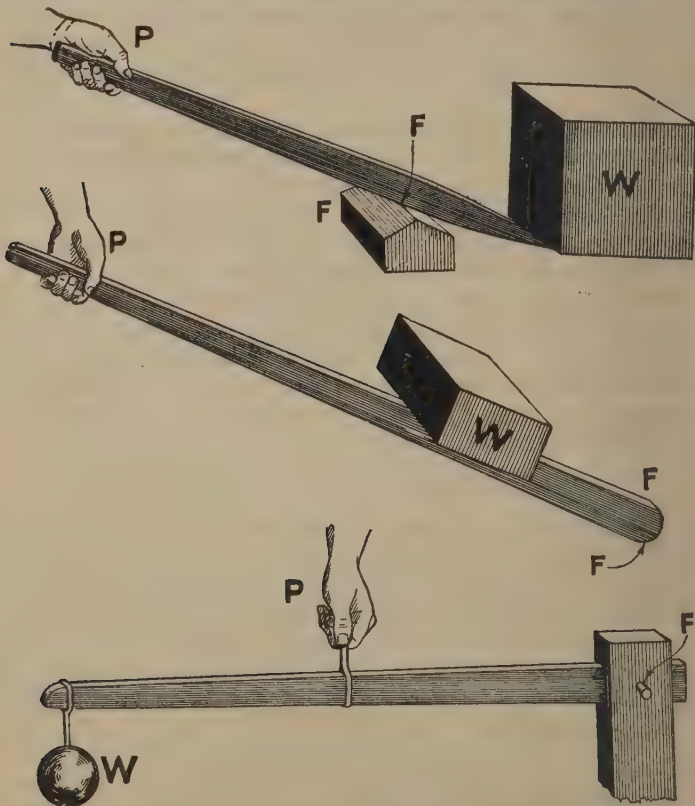
FIGS. 5,929 to 5,931.—The three kinds of lever. Fig. 5,929, lever of the first order; fig. 5,930, lever of the second order; fig. 5,931, lever of the third order.
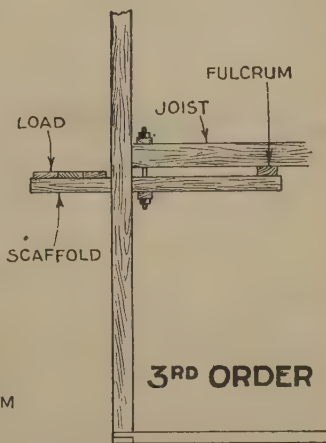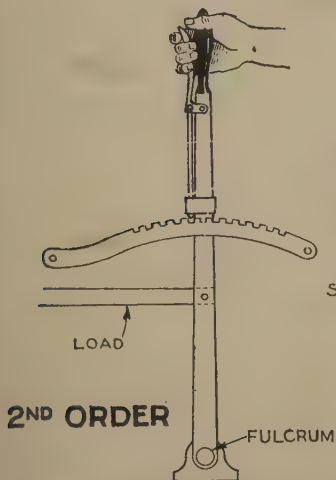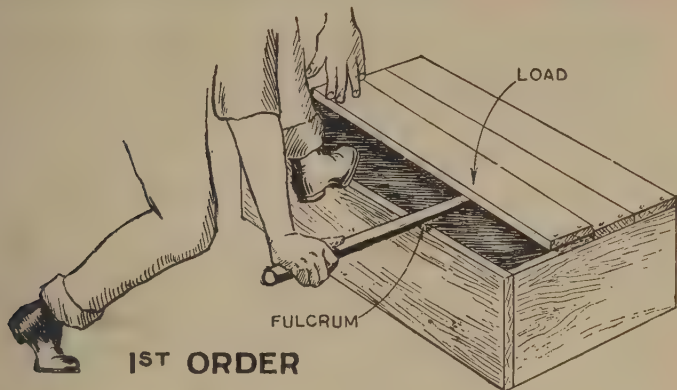
Figs. 5,932 to 5,934.—Familiar examples of the application of the three kinds of lever. Fig. 5,932, prying open box top with 1st order lever; fig. 5,933, reversing locomotive with 2nd order lever; fig. 5,934, supporting scaffold with 3rd order lever.

There are three varieties of the lever as shown in figs. 5,935 to 5,937, according as the fulcrum, the weight or the power is respectively placed between the other two, but the action in every case is reducible to the same principle and the same general rule applies to them all.

The following general rule holds for all classes of lever:

FIRST ORDER

P ↓   W

|← 36 →| F ▲ |← 6 →|

SECOND ORDER

W ↓

↑P   36   F ▲
                |← 6 →|

THIRD ORDER

W ↓   THIRD ORDER

P ↑ |← 6 →| F ▲

|← 36 →|
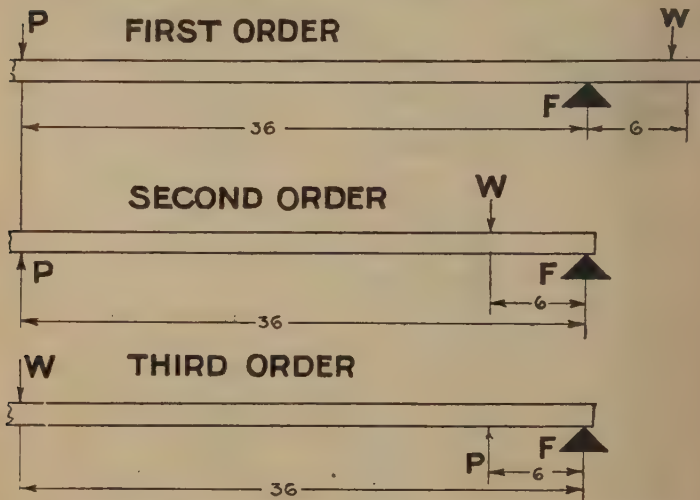
Figs. 5,935 to 5,937.—Diagrams of the three orders of lever illustrating the accompanying example.

Rule.—*The force P, multiplied by its distance from the fulcrum, is equal to the load W, multiplied by its distance from the fulcrum.* That is:

$$Force \times distance = load \times distance \dots\dots\dots(1)$$

Example.—What force applied at 3 ft. from the fulcrum will balance

a weight of 112 lbs. applied at 6 ins. from the fulcrum. Here the distances or "leverages" are 3 feet and 6 inches.

The distance must be of the same denomination; hence reducing ft. to ins., $3 \times 12 = 36$ ins.

Applying the rule

$$\text{Force} \times 36 = 112 \times 6$$

Solving

$$\text{Force} = \frac{112 \times 6}{36} = 18.67 \text{ or } 18\frac{2}{3} \text{ lbs.}$$

This solution holds for all levers as illustrated in figs. 5,935 to 5,937.*
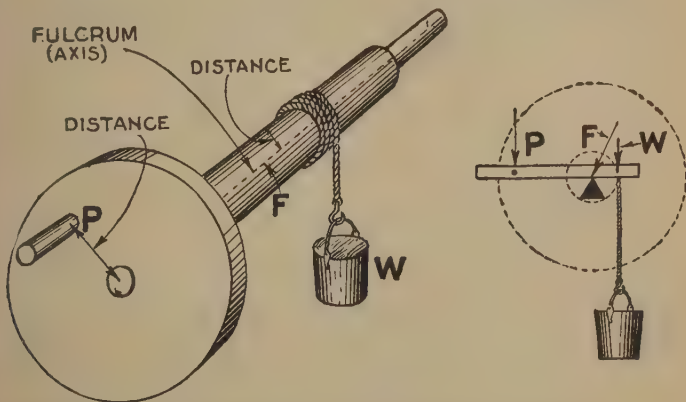
FIGS. 5,938 and 5,939.—Wheel and axle and comparison with the 1st order lever.

The Wheel and Axle.—This combination is virtually a continuous or revolving lever. It consists of a wheel fixed to an axle or drum so arranged that the operating force is applied to the wheel and load to the axle as above in fig. 5,938.

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*NOTE.—The author assumes the reader understands the solution of equations. If not the information will be found in Chap. 102, Methematics for Plumbers, also additional mathematics will be found in Vol. 2 of the Carpenters and Builders Guide.

Comparison of the wheel and axle with a 1st order lever shows that in principle they are the same thing. The general equation (1) on page 1,176 applies to the wheel and axle.

Chinese Wheel and Axle.—This is a modification of the wheel and axle and is used for obtaining extreme degree of leverage. Its principle and construction are shown in figs. 5,940 and 5,941.
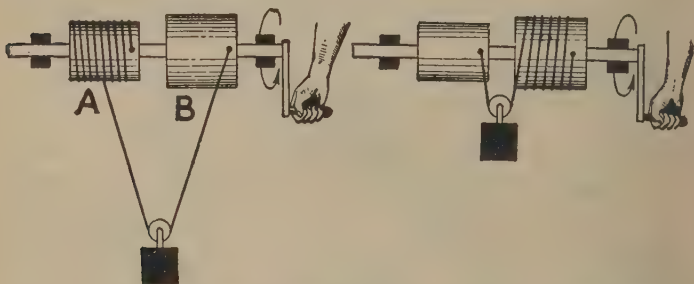
FIGS. 5,940 and 5,941.—Chinese windlass illustrating the principle of the differential hoist. *It consists of* two drums, A, and B (one a little larger than the other) connected to a shaft and having the ends of a lifting cable attached to the drum as shown, so that in turning the crank the cable will simultaneously unwind on one drum and wind on the other. Fig. 5,940 shows the beginning of the lifting operation. As the crank is turned clockwise the cable winds on B, and unwinds on A, and since B, is larger in diameter, the length of cable between the two drums and load is gradually taken up, thus lifting the load. Evidently by making the difference in diameter of the two drums very small an extremely large leverage is obtained, thus enabling very heavy weights to be lifted with little effort. The load will remain suspended at any point, *because the difference in the diameter of the two drums is too small to overbalance the friction of the parts.* Fig. 5,941 shows the end of the lifting operation.

The Pulley.—In its simplest form it consists of a grooved wheel called a sheave turning within a frame by means of a cord or rope which works in contact with the groove in order to transmit the force applied to the rope in another direction, as shown in fig. 5,942.

Pulleys are divided into *fixed* and *movable*. In the fixed pulley no

mechanical advantage is gained, but its use is of the greatest importance in accomplishing the work appropriate to the pulley, such as raising water from a well. The *movable* pulley, by distributing the weights into separate parts, is attended by mechanical advantages proportioned to the number of points of support.

Combinations of pulleys are arranged with several sheaves in one frame to form a block to increase the load that may be lifted per unit of force
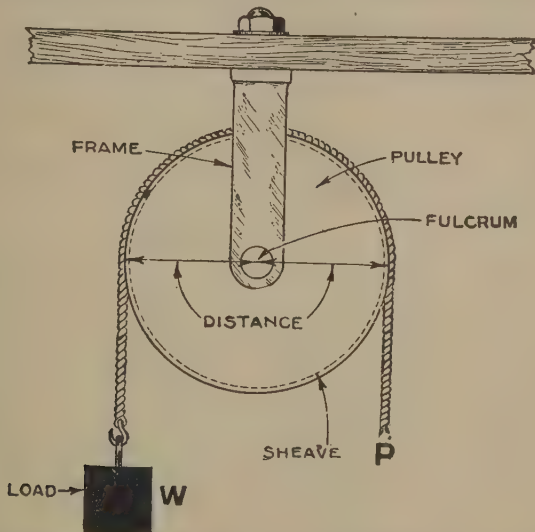
Fig. 5,942.—Simple pulley. *As seen,* the pivot forms the fulcrum and the distance from fulcrum to rope on each side, the leverage. Since these distances are equal there is no mechanical gain, that is force (P) =load (W). The object sought in the use of the simple pulley is to more conveniently apply the power by changing the direction of the lifting force P.

applied, in other words, to increase the leverage as all such arragements are virtually equivalents of the lever.

The following rule expresses the relation between the force and load.

Rule.—*The load capable of being lifted by combination of pulleys is equal to the force × the number of ropes supporting the lower or movable block.*

The Inclined Plane.—This mechanical power consists of an
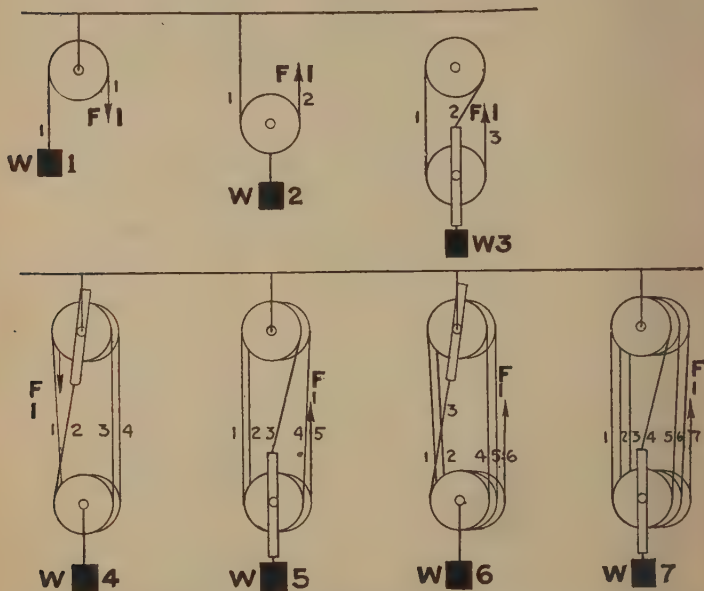
FIGS. 5,943 to 5,949.—Elementary pulley combinations illustrating accompanying rule for relation between force applied and load lifted and showing how the load may be increased from 1 to 7 times per unit of force applied. Of course a greater range may be secured by additional pulleys, but there is a limit in practice to which it is mechanically expedient.

inclined flat surface upon which a weight may be raised as shown in fig. 5,950.

By such substitution of a sloping path for a direct upward

efficacy from the lever or wheel work with which it is very easily combined.

A screw in one revolution will descend a distance equal to its pitch, or the distance between two threads and the force applied to the screw will move through, in the same time the circumference of a circle whose diameter is twice the length of the lever.

Rule.—*As the applied force is to the load so is the pitch to the length of thread per turn*, that is:

Applied force : load = pitch : length of thread per turn........(3)

Example:—If the distance between the threads or *pitch* be ¼ in. and a force of 100 lbs. be applied at the circumference of the screw. what weight will be moved by the screw, the length of thread per turn of the screw being 10 ins.

Substituting in equation (3)

$$100 : \text{load} = ¼ : 10$$
$$\text{load} \times ¼ = 10 \times 100$$
$$\text{load} = \frac{10 \times 100}{¼} = 4{,}000 \text{ lbs.}$$

The Wedge.—This is virtually a pair of inclined planes in contact along their bases or back to back. The wedge is generally driven by blows of a hammer or sledge instead of being pushed as in the case of the other powers; sometimes the wedge is moved by constant pressure.

If the weight rest on a horizontal plane and a wedge be forced under it, when the wedge has penetrated its length, the weight will be lifted a height equal to the thickness of the butt end of the wedge, as in figs. 5,953 and 5,954.

Figs. 5,951 and 5,952.—Evolution of the screw. If the inclined plane shown in fig. 5,950 be curved around into cylindrical form, it becomes one turn of a screw. Note that points L,A,R,F,G, of fig. 5,950 correspond to similar points of figs. 5,951 and 5,952. Thus G' of fig. 5,951 corresponds to G' of fig. 5,952. The incline may be continued by winding upward around the same axis any number of turns giving the screw as in fig. 5,952.

The Screw.—This is simply an inclined plane wrapped around a cylinder. The evolution of a screw from an inclined plane is shown in figs. 5,951 and 5,952.

The distance apart of two consecutive coils, measured from center to center, or from upper side to upper side (literally the height of the inclined plane), for one revolution, is "the pitch" of the screw.

The screw is generally employed when severe pressure is to be exerted through small spaces; being subject to great loss from friction it usually exerts but a small power of itself, but derives its principal

efficacy from the lever or wheel work with which it is very easily combined.

A screw in one revolution will descend a distance equal to its pitch, or the distance between two threads and the force applied to the screw will move through, in the same time the circumference of a circle whose diameter is twice the length of the lever.

Rule.—*As the applied force is to the load so is the pitch to the length of thread per turn*, that is:

Applied force : load = pitch : length of thread per turn........(3)

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The Wedge.—This is virtually a pair of inclined planes in contact along their bases or back to back.   The wedge is generally driven by blows of a hammer or sledge instead of being pushed as in the case of the other powers; sometimes the wedge is moved by constant pressure.

If the weight rest on a horizontal plane and a wedge be forced under it, when the wedge has penetrated its length, the weight will be lifted a height equal to the thickness of the butt end of the wedge, as in figs. 5,953 and 5,954.

Rule.—*As the applied force is to the load so is the thickness of the wedge to its length;* that is:

Applied force : load = thickness : length of wedge.....................(4)

Example.—What force is necessary to apply to a wedge 20 ins. long and 4 ins. thick to raise a load of 2,000 lbs.?

Substituting in equation (4)

Applied force : 2,000 = 4 : 20

20 : 4 = 2000 : applied force

applied force × 20 = 4 × 2000

applied force = $\frac{4 \times 2000}{20}$ = 400 lbs.
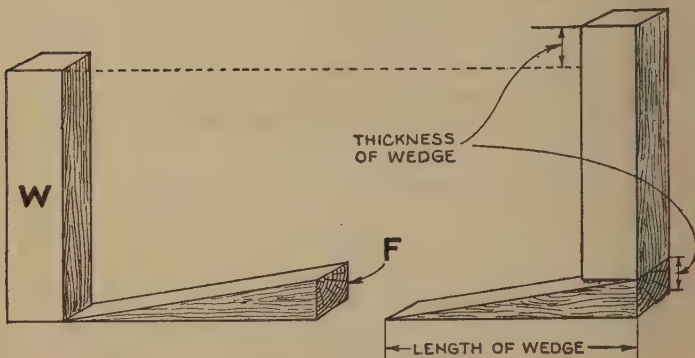
Figs. 5,953 and 5,954.—Application of the wedge in raising a heavy load.

Expansion and Contraction.—Practically all substances expand with increase in temperature and contract with decrease of temperature. The expansion of solid bodies in a longitudinal direction is known as *linear expansion;* the expansion in volume is called the *volumetric expansion.*

A notable exception to the general law for expansion is the behaviour of water. With decrease in temperature water will

contract until it reaches its minimum volume, at a temperature of 39.1° Fahr.; this is the point of maximum density. With continued decrease in temperature it will expand until it freezes and becomes ice, as shown in figs. 5,955 to 5,957. Were it not for this fact plumbers would be out of the job of repairing frozen pipes.
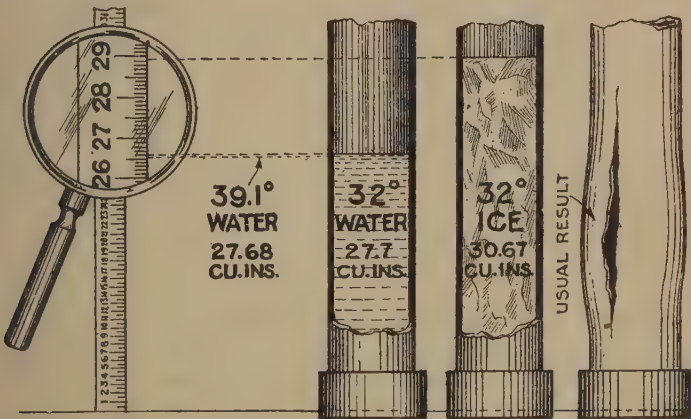
FIGS. 5,955 to 5,957.—Expansion of water from temperatures below 39.1°, which often causes pipes to burst. The illustrations show linear expansion of 1 lb. of water in a ¼ in. pipe to clearly illustrate relative volumes; fig. 5,957 shows what actually happens (volumetric expansion).

The following example will illustrate the use of the table on next page:

Example.—How much longer is a 36 in. rod of aluminum when heated from 97 to 200° Fahr.?

Increase in temperature 200−97 = 103°

Coefficient of expansion for aluminum from table = .00001234.

Increase in length of rod = 36 × .000001234 × 103 = .002 in.

Linear Expansion of Common Metals

(Between 32 and 212 degrees Fahr.)

	Linear expansion per unit length per degree Fahr.
Aluminum	.000001234
Antimony	.00000627
Bismuth	.00000975
Brass	.00000957
Bronze	.00000986
Copper	.00000887
Gold	.00000786
Iron, cast	.00000556
Iron, wrought	.00000648
Lead	.00001571
Nickel	.00000695
Steel	.00000636
Tin	.00001163
Zinc, cast \\ Zinc, rolled /	.00001407

Volumetric expansion = 3 × linear expansion.

Melting Point of Solids.—The temperatures at which a solid substance changes into a liquid is called the melting point. When a solid begins to melt, the temperature remains constant until the whole mass of the solid has changed into a liquid. The heat supplied during the period is used to change the substance from the solid to the liquid state and is called the *latent heat of fusion.*

For instance, to melt a lb. of ice at 32° Fahr., that is to convert it into water at the same temperature requires 143.57 B.t.u or 144 B.t.u. for ordinary calculations. The temperature at which melting takes place varies for different substances.

The following table gives the melting point for commercial metals:

Melting Points of Commercial Metals

	Degrees Fahr.
Aluminum	1,200
Antimony	1,150

Table—*Continued*

Degrees Fahr.

Bismuth	500
Brass	1,700–1,850
Copper	1,940
Cadmium	610
Iron, cast	2,300
Iron, wrought	2,900
Lead	620
Mercury	139
Steel	2,500
Tin	446
Zinc, cast	785

Impure metals usually have a lower melting point than pure metals. Low melting points may be obtained by combining several metals to form alloys. Often an alloy will melt at much lower temperature than would be expected considering the melting points of the metals of which it is composed. Those of the lowest melting point contain bismuth, lead, tin and cadmium.

By varying the percentages of each metal the melting points ranging from 149° to 324° Fahr. are obtained; these are only about ¼ the melting point of the constituent metals. Alloys having such low fusing points are known as *low fusing alloys*. These are considered further in the chapter on Soldering.

Gravity.—By definition gravity is *the force that attracts bodies, at or near the surface of the earth, toward the center of the earth*. This force varies at different points on the earth's surface. It is strongest at sea level, decreases below the level in same ratio that its distance from the center of the earth decreases; above the surface the attraction decreasing in ratio as the square of the distance from the center of the earth

increases. Thus a body weighs less on top a high mountain than at sea level.

Falling Bodies.—Under the influence of gravity *alone* all bodies fall to the earth with the same acceleration of velocity.

NO AIR INSIDE TUBE

FEATHER AND LEAD FALL TOGETHER

OPEN TO ATMOSPHERE

FEATHER

LEAD REACHES BOTTOM FIRST
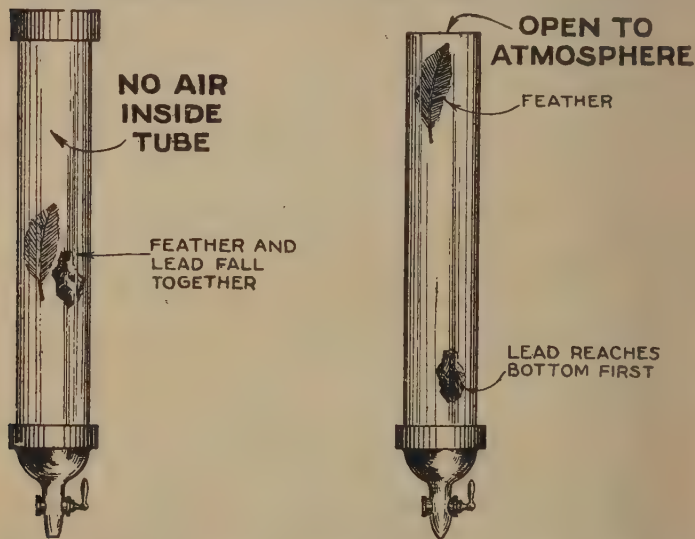
FIGS. 5,958 and 5,959.—Experiments with falling bodies. Place a feather and piece of lead in a long tube and pump out the air. If the tube be suddenly inverted it will be found that the two objects fall side by side from top to bottom as in fig. 5,958. If the top be left open so that the objects are surrounded by air, when the tube is inverted, as in fig. 5,959, it will be found that the lead reaches the bottom before the feather.

Galileo proved this by dropping balls of different sizes at the same instant from the top of the leaning tower of Pisa. The spectators saw the balls start together and heard them strike the ground together. Of course anybody knows that if, for instance, a feather and a piece of lead were released at the same time from an elevated point, the lead would reach the earth first. It is not the difference in weight that retards the feather but the effect of the air on the less dense object.

In a vacuum all bodies fall with the same acceleration of velocity as has been proved by the experiment illustrated in figs. 5,958 and 5,959.

Center of Gravity.—Briefly, the center of gravity of a body is *that point of the body about which all its parts are balanced, or which being supported, the whole body will remain at rest, though acted upon by gravity.*

The center of gravity may be found by calculation, and in some cases, more conveniently by experiments, as in fig. 5,960.
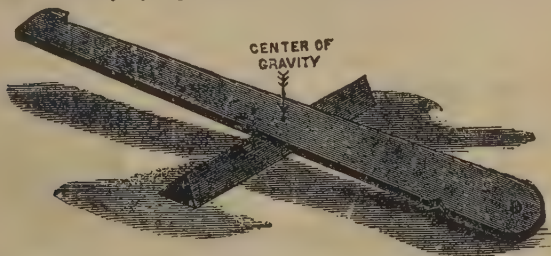
CENTER OF GRAVITY

Fig. 5,960.—Method of finding the center of gravity of the lever. The center of gravity of the lever is the point where the bar would be in equilibrium if balanced over a knife edge or any other support with a sharp corner placed at right angles to the lever, as shown in the figure.

Momentum.—In popular language momentum may be defined as *the power of overcoming resistance as possessed by a body by virtue of its motion;* that which makes a moving body hard to stop. Numerically it is equal to the product of mass of the body multiplied by its velocity. It is numerically equivalent to the number of pounds of force that will stop a moving body in 1 second, or the number of pounds of force which acting during 1 second will give it the given velocity.

Friction.—By definition, friction is *that force which acts between two bodies at their surface of contact so as to resist their*
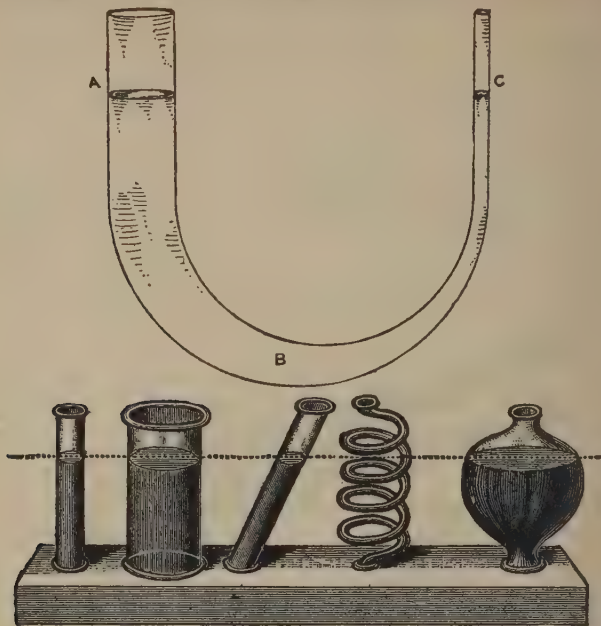
FIGS. 5,961 and 5,962.—*Hydraulic principles: 1. Fluids rise to the same level in the opposite arms of a U tube.* Let A,B,C, be a recurved tube; if water be poured into one arm of the tube it will rise to the same height in the other arm because the pressures acting upon the lowest part at B, in opposite directions, are proportioned to its depth below the surface of the fluid. Therefore, these depths must be equal, that is, the height of the two columns must be equal, in order that the fluid at B, may be at rest. Unless this part be at rest, the other parts of the column cannot be at rest. Moreover, since the equilibrium depends on nothing else than the heights of the respective columns, therefore, the opposite columns may differ to any degree in quantity, shape, or inclination to the horizon. Thus, if vessels and tubes vary diversely in shape and capacity, as in fig. 5,962, be connected with a reservoir, and water be poured into any one of them, it will rise to the same level in all of them. The reason of this fact will be further understood from the application of the principle of equal moments, for it will be seen that the velocity of the columns, when in motion, will be as much greater in the smaller than in the larger columns, as the quantity of matter is less; and hence the opposite moments will be constantly equal. Hence, water conveyed in aqueducts or running in natural channels, will rise just as high as its source. Between the place where the water of an aqueduct is delivered and the spring, the ground may rise into hills and descend into valleys, and the pipes which convey the water may follow all the undulations of the country, and the water will run freely, provided no pipe be laid higher than the spring.

sliding on each other; it is the resistance to motion when one body is moved upon another.

Were it not for friction many things would be impossible in mechanics; for instance, power could not be transmitted by belts, automobiles could not be driven through clutches, etc., etc. Because of friction bearings must be lubricated, long pipe lines must be over size to prevent undue loss of pressure, etc. The object of lubrication of bearings is to form a film of oil so that the revolving part does not touch the bearing but revolves on a thin film of oil, the friction of solids on fluids being much less than that between solids. Ordinary bearings absorb from 3 to 5% of the applied power; roller bearings 2%; ball bearings 1%; spur gears with cast teeth, including bearings, 7%; spur gears with cut teeth 4%; bevel gears with cast teeth, including bearings, 8%; bevel gears with cut teeth, including bearings, 5%; belting 2 to 4%; roller chains 3 to 5%.

Hydraulics.—The term *hydraulics* is commonly, though ill advisedly, defined as *the science which treats of liquids, especially water in motion.* **Properly speaking** there are two general divisions of the subject:

1. Hydrostatics.
2. Hydrodynamics.

Hydrostatics refers to liquids *at rest,* and hydrodynamics to liquids *in motion.* The outline here given relates to water.

Water.—Those who have had experience in the design or operation of pumps, have found that water is an unyielding substance when confined in pipes and pump passages, thus necessitating very substantial construction to withstand the pressure, and periodic shocks or water hammer.

Water at its maximum density (39.1° Fahr.) will expand

as heat is added, and it will also expand slightly as the temperature falls from this point.

For ordinary calculations the weight of 1 cu. ft. of water is taken at 62.4 lbs., which is correct when its temperature is 53° Fahr.

The figure 62.5 usually given is approximate. The highest authoritative figure is 62.428. At 62° Fahr., the figures range from 62.291 to 62.36. The figure 62.355 is generally accepted as the most accurate.

The weight of a U. S. gallon of water, or 231 cu. ins. is roughly 8⅓ lbs.
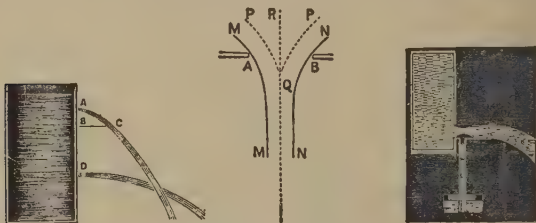
FIGS. 5,963 to 5,965.—*Flow of Water Under Pressure.* If an orifice in a vessel look downward and the column of liquid over it be short, this will simply drop out by its own weight, starting at a velocity of 0. But if a considerable depth of liquid be above, its gravity produces a corresponding pressure on its base, or on that liquid which is near it; so that, if a plug be removed from an orifice in or close to the base, the liquid starts at once into rapid motion. Each particle of a jet A issuing from the side of a vessel fig. 5,963, moves horizontally with the velocity above mentioned, *but it is at once drawn downward by the force of gravity*, describing a *parabola* in the same manner as a bullet fired from a gun, with its axis horizontal. If the water issue through orifices which are small in comparison with the contents of the vessel, the jets from orifices at different depths below the surface take different forms, as shown at D. *Quantity of Efflux.* If the bottom of a vessel containing water be thin, and the orifice be a small circle whose area is *a* (see fig. 5,964) where AB, represents an orifice in the bottom of a vessel, every particle above AB, tries to pass out of the vessel, at once, and in so doing exerts a pressure on those nearest. Those that issue near A and B, exert pressures in the directions M.M. and N,N, those near the center of the orifice in the direction R,Q, those in the intermediate parts in the directions PQ, PQ. In consequence, the water within the space PQP, is unable to escape, and that which does escape, instead of assuming a cylindrical form, at first contracts, and takes the form of a truncated cone. It is found that the escaping jet continues to contract until at a distance from the orifice about equal to the diameter of the orifice; this part of the jet is called the *vena contracta* or contracted vein. *Influence of tubes on the quantity of efflux.* If a cylindrical or conical efflux tube be fitted to the aperture, the amount of the flow is considerably increased. A short tube, whose length is from two to three times its diameter, has been found to increase the actual efflux per second to about 82 per cent of the theoretical. In this case, the water on entering the tube, forms a contracted vein, fig. 5,965, just as it would do on issuing freely into the air, but afterwards it expands, and because of the adhesion of the water to the interior surface of the tube, has, on leaving the tube, a section greater than that of the contracted vein. The contraction of the jet within the tube shown in block in the figures, causes a partial vacuum.

Head and Pressure.—These are the two primary considerations in hydraulics. The word head signifies *the difference in level of water between two points*, and it is usually expressed in feet.

There are two kinds of head:

1. Static head.
2. Dynamic head.

> *The static head is the height from a given point of a column, or body of water at rest,* considered as causing or measuring pressure.
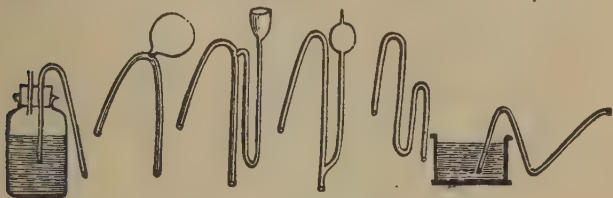
Figs. 5,966 to 5,971.—*Hydraulic Principles: 2. The siphon.* This device consists of a bent pipe or tube with legs of unequal length, used for drawing liquid out of a vessel by causing it to rise in the tube over the rim or top. For this purpose the shorter leg is inserted in the liquid, and the air is exhausted by being drawn through the longer leg. The liquid then rises by the pressure of the atmosphere and fills the tube and the flow begins from the lower end. The general method of use is to fill the tube in the first place with the liquid, and then, stopping the mouth of the longer leg, to insert the shorter leg in the vessel; upon removal of the stop, the liquid will immediately begin to run. The flow depends upon the difference in vertical height of the two columns of the liquids, measured respectively from the bend of the tube, to the level of the water in the vessel and to the open end of the tube. The flow ceases as soon as, by the lowering of the level in the vessel, these columns become of equal height or when the level descends to the end of the shorter leg. The atmospheric pressure is essential to the support of the column of liquid from the vessel up to the top of the bend of the tube, and this height is consequently limited; at sea height the maximum height is a little less than 34 feet for water, but this varies according to *the density of the fluid.*

> *The dynamic head is an equivalent or virtual head of water in motion which represents the resultant pressure due to the height of the water from a given point, and the resistance to flow due to friction.*

Thus, when water is made to flow through pipes or nozzles there is a loss of head. These terms are illustrated in fig. 5,972. Here the dynamic head is *greater* than the static head in the supply line to the tank, and *less* in the tank discharge line because of frictional resistance to the flow of the water. In ordinary calculations, it is common practice to estimate

that every foot head is equal to one-half pound pressure per sq. in., as this allows for ordinary friction in pipes.

The following distinctions with reference to head should be carefully noted.

Total static head = static lift + static head.

Total dynamic head = dynamic lift + dynamic head.

Lift.—When the barometer reads 30 inches at sea level, the
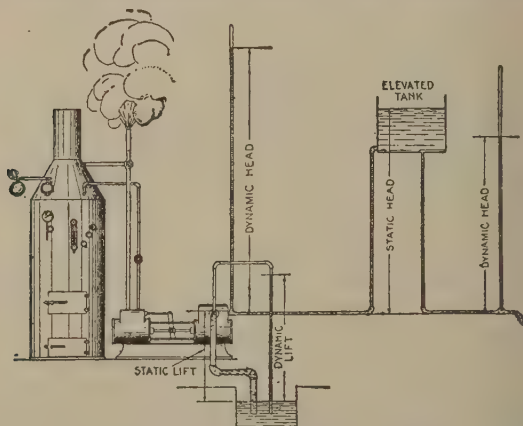
Fig. 5,972.—View of elevated tank with pump in operation maintaining the supply which is being drawn upon as shown, illustrating the terms static lift, dynamic lift, static head, and dynamic head.

pressure of the atmosphere at that elevation is 14.74 lbs. per sq. in., that is to say, this pressure will maintain or balance a column of water 34.042 ft. high when the column is completely exhausted of air, and the water is at a temperature of 62° Fahr. In other words, the pressure of the atmosphere then *lifts* the water to such height as will establish equilibrium between the weight of the water and the pressure of the air. Similarly in

pump operation, the receding piston or plunger establishes the vacuum and the pressure of the atmosphere lifts the water from the level of the supply to the level of the pump. Accordingly *lift* as related to pump operation may be defined as *the height in feet from the surface of the intake supply to the pump*.
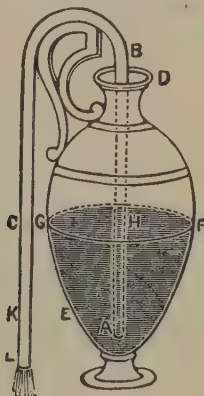
FIG. 5,973.—The *syphon*. Let ABC, be a bent syphon, or tube, of which the leg AB, is plunged into a vessel DE, containing water. If the surface of the water be FG, the leg of the syphon, AB, will be filled with water as high as the surface, that is, up to H, the portion of HBC, remaining full of air. If, then, the air be drawn off by suction through the tube C, the liquid also will follow. And if the tube C, be level with the surface of the water, the syphon, though full, will not discharge the water, but will remain full: so that, although it is contrary to nature for water to rise, it has risen so as to fill the tube ABC, and the water will remain in equilibrium, like the beams of a balance, the portion H,B, being raised on high, and the portion BC, suspended. But if the outer mouth of the syphon be lower than the surface FG, as at K, the water flows out, for the liquid in KB, being heavier, overpowers and draws toward it the liquid BH. The discharge, however, continues only until the surface of the water is on a level with the mouth K, when, for the same reason as before, the efflux ceases. But if the outer mouth of the tube be lower than K, as at L, the discharge continues until the surface of the water reaches the mouth A.

Strictly speaking, it is the height to which the water is elevated by atmospheric pressure, which in some pumps may be measured by the elevation of the inlet valves, and in others by the elevation of the piston.

The practical limit of lift is 20 to 25 ft.

Long inlet lines, multiplicity of inlet elbows, and high tem-
perature of the water require shorter lifts.

*The lift must be reduced as the temperature of the water is
increased* because the boiling point of water corresponds to
the pressure.

Theoretically a perfect pump will draw water from a height of 34 ft
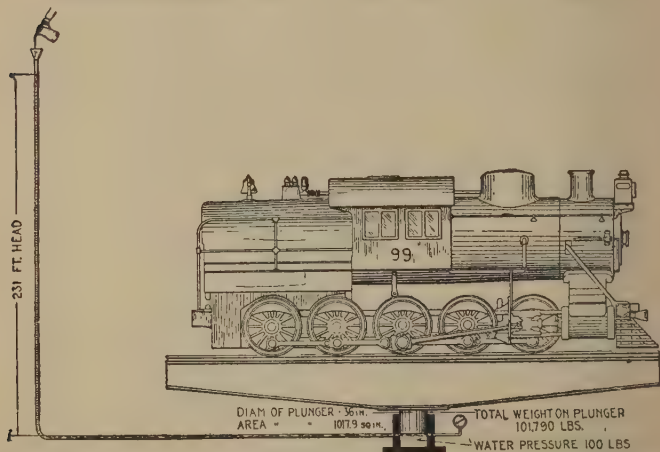
Fɪɢ. 5,974.—**Hydraulic principles: 3.** Any quantity of water however small may be made
to balance any weight however great. The figure shows a locomotive on a turn table bal-
anced by a hydraulic pivot or plunger. Assuming no leakage or friction at the joint, and
that the vertical pipe leading to the plunger cylinder is very small, it is evident that it
could be filled to the elevation shown with a very small quantity of water—say one quart.
If the total weight of locomotive, turn table, etc., and the plunger be 101,709 lbs., and the
plunger area be 1,017.9 sq. ins., then the water pressure per sq. in. on the piston necessary
to balance the load =101,796 ÷1,017.9 =100 lbs. Hence the load will be balanced when
the pipe is filled with water to a height of 100 ×2.31 =231 ft.

when the barometer reads 30 ins., but since a perfect vacuum cannot
be obtained on account of valve leakage, air contained in the water *and
the vapor of the water itself*, the actual height is generally less than 30 feet,
and for warm or hot water considerably less.

When the water is warm, the height to which it can be lifted decreases,
on account of the increased pressure of the vapor. That is to say, for

Fig. 5,975.—*Height of a jet.*—If a jet, issuing from an orifice in a vertical direction have the same velocity as a body would have which fell from the surface of the liquid to that orifice, the jet ought to rise to the level of the liquid. It does not, however, reach this; for the particles which fall hinder it. But by inclining the jet at a small angle with the vertical it reaches about nine-tenths of the theoretical height, the difference being due to friction and to the resistance of the air. *The quantities of water which issue from orifices of different areas are very nearly proportional to the size of the orifice*, provided the level remain constant, and this is true irrespective of the form of the opening which may be round, square, or any other shape.
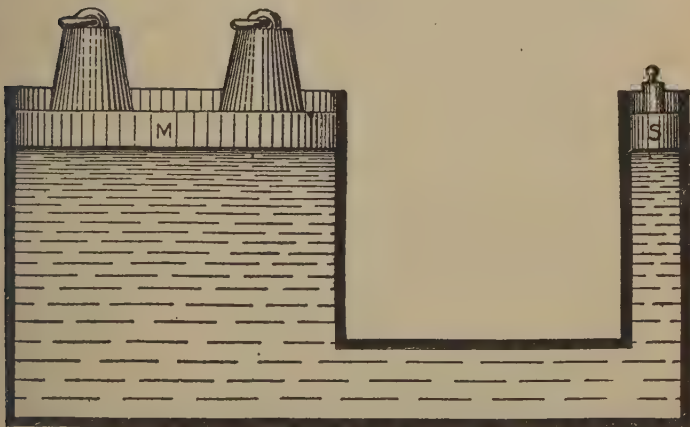
Fig. 5,976.—*Hydraulic principles: 4. The pressure exerted by a liquid on a surface is proportional to the area of the surface.* Two cylinders of different diameter are joined by a tube and filled with water. On the surface of the two pistons M, and S, which hermetically close the cylinders, but move without friction. Let the area of the large piston M, be, say thirty times that of the smaller one S, and let a weight, say of two pounds, be placed upon the small piston. The pressure will be transmitted to the water and to the large piston, and as this pressure amounts to two pounds in each portion of its surface equal to that of the small piston, the large piston must be exposed to an upward pressure thirty times as much, or 60 lbs. If now a 60 lb. weight be placed upon the large piston, both pistons will remain in equilibrium, but if the weight be greater or less, the equilibrium will be destroyed.

illustration, a boiler feed pump taking water at say 153° Fahr., could not produce a vacuum greater than 20.78 ins., because at that point the water would begin to boil and fill the pump chamber with steam Accordingly, the theoretical lift corresponding would be

$$34 \times \frac{21.78}{30} = 24.68 \text{ ft. approximately.}$$

The result is approximate because no correction has been made for the 34 which represents a 34 foot column of water at 62°; of course, at 153° the length of such column would be slightly increased.

It should be noted that the figure 24.68 ft. is the *approximate* theoretical lift for water at 153°; the *practical* lift would be considerably less.

The following table shows the theoretical maximum lift for different temperatures, leakage not considered.

Theoretical Lift for Various Temperatures

Temp. Fahr.	Absolute pressure of vapor lbs. per sq. ins.	Vacuum in inches of mercury	Lift in feet	Temp. Fahr.	Absolute pressure of vapor lbs. per sq. ins.	Vacuum in inches of mercury	Lift in feet
102.1	1	27.88	31.6	182.9	8	13.63	15.4
126.3	2	25.85	29.3	188.3	9	11.6	13.0
141.6	3	23.83	27	193.2	10	9.56	10.8
153.1	4	21.78	24.7	197.8	11	7.52	8.5
162.3	5	19.74	22.3	202	12	5.49	6.2
170.1	6	17.70	20	205.9	13	3.45	3.9
176.9	7	15.67	17.7	209.6	14	1.41	1.6

Flow of Water in Pipes.—The quantity of water discharged through a pipe depends upon:

1. The *head*, that is, the vertical distance between the level surface of still water in the chamber at the entrance end of the pipe and the level of the center of the discharge end of the pipe.

2. The length of the pipe.

3. The character of its interior surface as to smoothness.

4. The number and sharpness of the bends, but is independent of the position of the pipe, as horizontal, or inclined
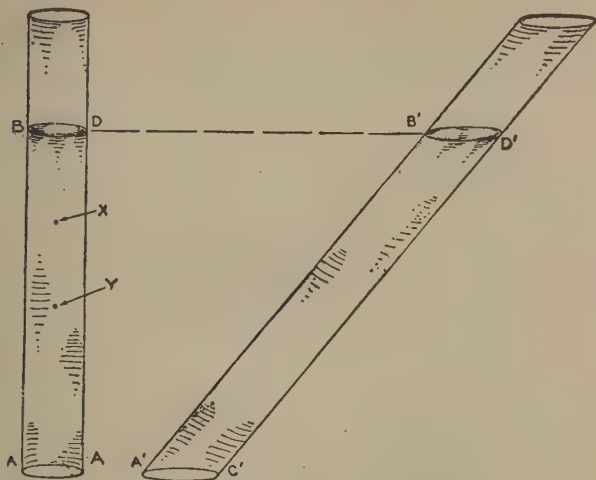
FIGS. 5,977 and 5,978.—*Hydraulic principles: 5. The pressure upon any particle of a fluid of uniform density is proportional to its depth below the surface.* **Example 1.** Let the column of fluid ABDA, fig. 5,977, be perpendicular to the horizon. Take any points, X, and Y, at different depths, and conceive the column to be divided into a number of equal space by horizontal planes. Then, since the density of the fluid is uniform throughout, the pressure upon X and Y, respectively, must be in proportion to the number of equal space above them, and consequently in proportion to their depths. **Example 2.** Let the column be of the same perpendicular height as before, but inclined as is fig. 5,978; then its quantity and of course its weight, is *increased* in the same ratio as its length exceeds its height; but since the column is partly supported by the plane, like any other heavy body, the force of gravity acting upon it is *diminished* on this account in the same ratio as its length exceeds its height; therefore as much as the pressure on the base would be augmented by the increased length of the column, just so much it is lessened by the action of the inclined plane, and the pressure of any part of C',D', will be, as before, proportioned to its perpendicular depth, and the pressure of the inclined column A',C',D',B', will be the same as that of the perpendicular column ABDC.

NOTE.—*The total head* operating to cause flow *is divided* into *three parts:* **1,** *the velocity head,* which is the height through which a body must fall in a vacuum to acquire the velocity with which the water flows into the pipe $= v2 \div 2g$, in which v is the velocity in ft. per sec. and $2g = 64.32$; **2,** *the entry head* required to overcome the resistance to entrance to the pipe. With sharp edged entrance, the *entry head = about ½ the velocity head* with smooth rounded entrance, the entry head is inappreciable; **3,** *the friction head,* due to the frictional resistance to flow within the pipe. In ordinary cases of pipes of considerable length the sum of the entry and velocity heads required scarcely exceeds one foot. In the case of long pipes with low heads, the sum of the velocity and entry heads is generally so small that it may be neglected.
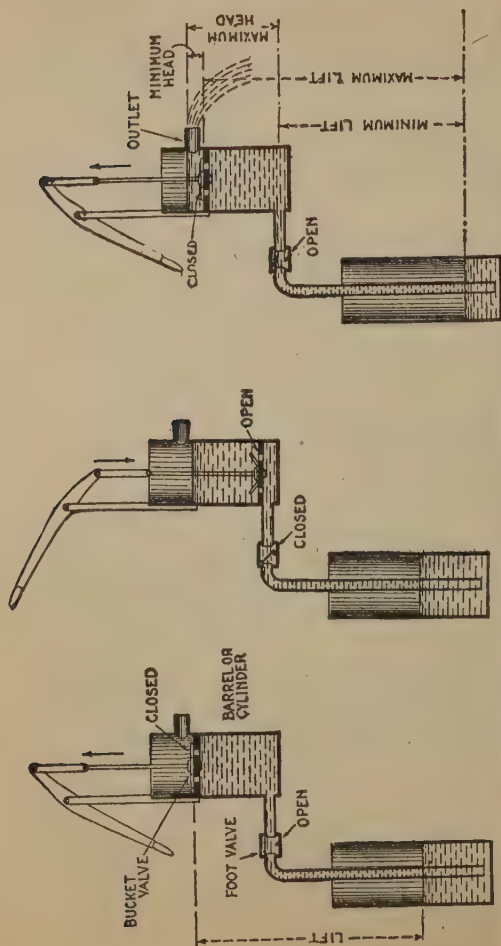
Figs. 5,979 to 5.981.—Elementary single acting lift pump showing essential features and cycle of operation.

upward or downward. The head, instead of being an actual distance between levels, may be caused by pressure, as by a pump, in which case the head is calculated as a vertical distance corresponding to the pressure, 1 lb. per sq. in. = 2.309 ft. head, or 1 ft. head = .433 lb. per sq. in.

Elementary Pumps.—There are three elements necessary for the operation of a pump:

1. Inlet or suction valve.
2. Piston or plunger.
3. Discharge valve.

Simple pumps may be divided into two classes:

1. Lift pumps.
2. Force pumps.

A lift pump is one which does not elevate the water higher than the lift; a force pump operates against both lift and head.

Lift Pumps.—Figs. 5,979 to 5,981 show the essentials and working principle of a simple lift pump.

In construction there are two valves in this type of pump, which are known as the foot valve and the bucket valve. *In operation* during the up stroke the bucket valve is closed and foot valve open, allowing the atmosphere to force the water into the cylinder.

When the piston begins to descend, the foot valve closes and bucket valve opens, which transfers the water in the cylinder from the lower side of the piston to the upper side as in fig. 5,980.

During the next up stroke, the water, already transferred to the upper side of the piston, is discharged through the outlet as in fig. 5,981.

It will be noted that as the piston begins the up stroke of discharge it is subject to a small maximum head, and at the end of the up stroke to a minimum head as indicated in fig. 5,981. This variable head is so small in comparison to the head against which a force pump works that it is not ordinarily considered.

Force Pumps.—The essential feature of a force pump which distinguishes it from a lift pump is that *the cylinder is always closed*, whereas in a lift pump it *is alternately closed and open* when the piston is respectively at the upper and lower ends of its stroke.

As shown in figs. 5,982 to 5,984, the cylinder top is closed by a cover, the piston rod passing through a stuffing box; this keeps the cylinder closed.
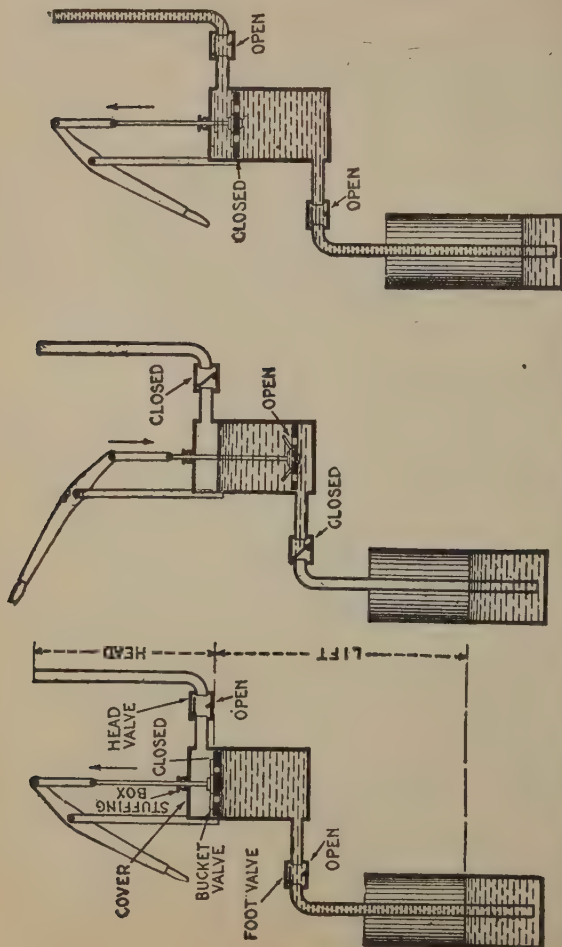
FIGS. 5,982 to 5,984.—Elementary single acting force pump showing distinguishing feature of closed cylinder.

In addition to the foot and bucket valves of the lift pump, a head valve is provided.

In operation, during the up stroke, atmospheric pressure forces water into the cylinder as in fig. 5,982; during the down stroke this water is transferred from the lower to the upper side of the piston as in fig. 5,983;

during the next up stroke, the piston forces the water out of the cylinder through the head valve which closes when the piston reaches the end of the stroke and the cycle is repeated. The positions of the valve are shown in the cuts.

A simple form of force pump is one known as a single acting plunger pump, a type extensively used, its cycle of operation being shown in figs. 5,985 and 5,986. The figures show the distinguishing features, such as closed cylinder, plunger, and only two valves.

In operation during the up stroke, water fills the cylinder, inlet valve
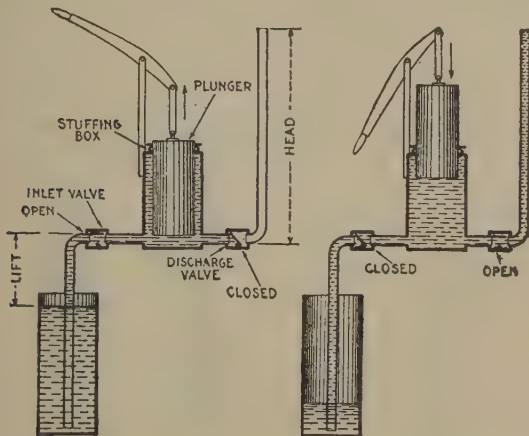
FIGS. 5,985 and 5,986.—**Elementary** single acting plunger pump showing essential parts. The distinction between a plunger and a piston should be carefully noted.

opens, and outlet valve closes, as shown in fig. 5,985. During the down stroke, the plunger "displaces" the water in the barrel, forcing it through the discharge valve against the pressure due to the head as in fig. 5,986.

Distinction Between Piston and Plunger.—A piston is *shorter* than the stroke, whereas a plunger is *longer* than the stroke.

The word plunger is very frequently used *erroneously* for piston even by those who ought to know better.

Double Acting Force Pump.—*By fitting a set of **inlet and outlet** valve at each end of a pump cylinder it is rendered **double acting,** that is, a cylinder full of water is pumped each stroke* instead of every other stroke.

With this arrangement the piston need have approximately only half the area of the single acting piston for equal displacement, and accordingly the maximum stresses brought on the reciprocating parts are reduced approximately one-half, thus permitting lighter and more compact construction.
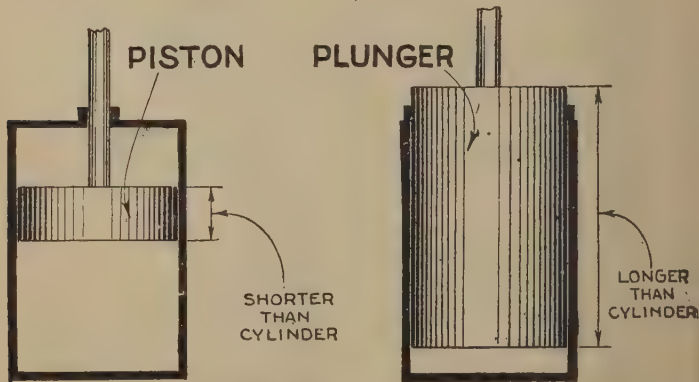
Figs. 5,987 and 5,988.—Distinction between piston and plunger: *A piston is shorter than the cylinder; a plunger, longer.* The erroneous and careless use of the two words is inexcusable.

In the double acting pump there are no bucket valves, a solid piston being used. The essential features and operation are plainly shown in figs. 5,989 and 5,990. There are two inlet valves A,B, and two discharge valves C, D, the cylinder being closed and provided with a piston.

In operation, during the down stroke, water follows the upper face of the piston through valve A. At the same time the previous charge is forced out of the cylinder through valve D, by the lower face of the piston.

During these simultaneous operations valves A and D, remain open, and B and C, closed, as in fig. 5,989.

During the up stroke, water follows the lower face of the piston through valve B. At the same time, the previous charge is forced out of the cylinder through valve C, by the upper face of the piston. During these simultaneous operations, valves B and C, remain open, and A and D, closed.
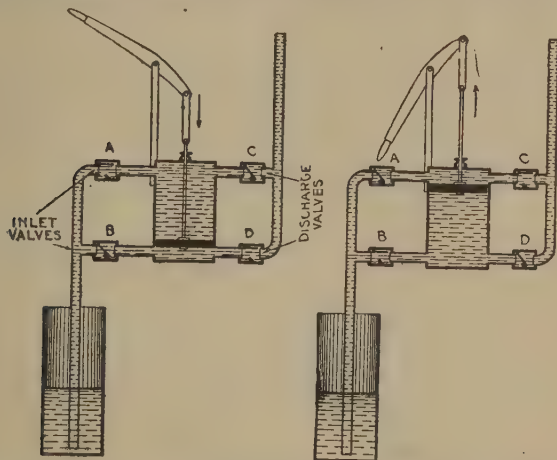
Figs. 5,989 and 5,990.—Elementary double acting force pump. *It is a combination* of two single acting pumps and gives a nearer uniform flow than the single acting pump.

NOTE.—*The raising of water* is one of the early arts; beginning in ancient times with devices of the crudest form it has followed the progress of civilization with ever increasing importance. In the present era, it demands engineering ability of the highest order and the finest of machinery.

NOTE.—*Important epochs* in the gradual inventions relating to pumps and hydraulics are: 1, the force pump, due to Ctesibius 200 B.C.; 2, the double acting pump, invented by La Hire in 1718; 3, the hydraulic ram, by Whitehurst in 1772; 4, the hydraulic press, introduced by Joseph Bramah in 1802.

NOTE.—*The term hydraulic,* so familiar in daily use, is formed from two Greek words meaning; 1, water; 2, a pipe; hence, it will be observed with interest how close the original meaning follows the development of the science in its practical adaptation; there is always the pipe or holding vessel and the water or its equivalent.

NOTE.—*Water flowing* from a reservoir through hydraulic engines gives back the energy expended, less so much as has been wasted in friction   Where a continuously acting steam engine stores up energy by pumping the water, and the work done by the hydraulic engines is done intermittently, this arrangement is considered the most useful.

NOTE.—*Wherever a stream flows* from a higher to a lower level it is possible to erect a water motor. The amount of power obtainable depends on the available head and the supply of water. In choosing a site the engineer will select a portion of the stream where there is an abrupt natural fall, or at least a considerable slope of the bed. He will have regard to the facility of constructing the channels which are to convey the water, and will take advantage of any bend in the river which enables him to shorten them. He will have accurate measurements made of the quantity of water flowing in the stream, and he will endeavor to ascertain the average quantity available throughout the year, the minimum quantity in dry seasons, and the maximum for which bye wash channels must be provided. In many cases the natural fall can be increased by a dam or weir thrown across the stream. The engineer will also examine to what extent the head may vary in different seasons, and whether it is necessary to sacrifice part of the fall and give a steep slope to the tail race to prevent the motor being flooded by backwater in freshet time.

CHAPTER 104

Plumbers' Materials

The plumber in his work comes in contact with many articles such as pipes, fittings, fixtures, etc., made of various materials such as lead, iron, brass, etc. These metals are the *raw materials* from which the articles are made, and the well informed workman should know something about the raw materials, their properties or behaviour under various working conditions so that he can properly perform such operations on them that may be necessary in the work of installing any plumbing system.

For instance, he should know that whereas lead melts at comparatively low temperature, if a small blow torch be applied to the lead packing in the spigot joint of a cast iron drainage pipe, the heat would be carried off so fast by the pipe by *conduction* that the flame from the blow torch would not even soften the lead.

Cast Iron.—According to the specifications adopted by the International Association for Testing Materials *cast iron* is defined as *iron containing so much carbon that it is not **malleable** at any temperature*. It consists of a mixture and combination of iron and carbon, with other substances in varying proportions.

Generally, commercial cast iron has between 3% and 4% of carbon. The carbon may be present as graphite as in *gray* cast iron, or in the form of combined carbon as in *white* cast iron.

In most cases the carbon is present in both forms. Besides carbon, silica, sulphur, manganese, and phosphorous are nearly always present.

Malleable Iron.—The method of producing malleable iron

is to convert the combined carbon of white cast iron into an amorphous uncombined condition, by heating the white cast iron to a temperature somewhere between 1,380° and 2,000° F.

The iron (or castings as sometimes called) is packed in retorts or annealing pots, together with an oxide of iron (usually hematite ore). The oxygen in the ore absorbs the carbon in the iron, giving the latter a steel like nature.

An annealing furnace or oven is used for heating, and the castings are kept red hot for several days or several weeks, depending upon the pieces. In order that the process be successful, the iron must have nearly all the carbon in the combined state, and must be low in sulphur, as the latter substance is found to greatly increase the time necessary.

Usually only good charcoal melted iron low in sulphur is used, though a coke melted iron is quite as suitable, provided the proportion of sulphur be small.

The process is not adapted to very large castings, because they cool slowly, and usually show a considerable proportion of graphite.

Wrought Iron.—By definition, wrought iron is *a slag bearing malleable iron which contains comparatively little carbon.* Nearly all the wrought iron now used is made by the ***puddling process.***

This process leaves the metal in the condition of a soft plastic ball saturated with slag. This ball is taken from the furnace and dropped into a machine which squeezes out most of the slag. It is then passed through a train of rolls which ejects much of the remaining slag and gives the plastic mass the form of a *bar*.

In the making of ***boiler plates,*** the muck bar, as it is called, is cut up into strips; enough strips to produce a sheet of the desired size are bound into a bundle, the bundle is then brought to a welding heat and passed through the rolls. Thus it is that a wrought iron plate consists of a series of welds. This accounts for its laminar structure.

The presence of slag in the material contributes largely to its fibrous texture, the rolls drawing the metal out into a stringy mass, each fibre of iron being, in fact, the core of a slender thread of slag.

Wrought iron is graded in several ways, there being no standard system. It is sometimes divided into two classes: 1, *charcoal* iron, which is made from charcoal pig and usually refined and double refined; and 2, *common iron*, which is made from coke pig.

According to another system, it is classed as: 1, charcoal iron; 2, puddle iron; and 3, busheled scrap iron.

Steel.—At the present time, steel is the most important material of construction. Its low price, combined with its great strength, permits its application to the largest and most severely strained constructive members. It can be forged or cast in any convenient form and is readily obtained in form of plates, bars and other shapes.

A disadvantage is that it is rather readily influenced by rust and corrosion, requiring systematic and careful attention in order to preserve it against the action of moisture, oxygen and carbonic acid, and insure its continued usefulness.

It is also attacked by galvanic action, in connection with copper or brass, upon immersion in a polarizing fluid.

In regard to its percentage of carbon, steel occupies a middle position between cast iron and wrought iron. In common with the former, it has a sufficiently low melting point for casting, and, in common with the latter, a sufficient toughness for forging.

According to their varying percentages of carbon, three kinds of steel may be recognized.

1. Soft steel.
2. Medium steel.
3. Hard steel.

Soft steel is nearest to wrought iron in carbon percentage and qualities, being soft, readily forged, and, by careful handling, may also be welded. It is principally used in the flanged parts, furnace plates, rivets and other details, which are exposed to alternate heating and cooling, or to severe treatment by shaping and forming.

Medium steel is harder than soft steel and is used for boiler shells

Cast steel has about the same percentage of carbon as soft or medium steel. It has in addition silicon and manganese which are needed to produce good castings.

Hard steel comes the nearest to cast iron in carbon percentage, and

possesses, as its most important quality, a decided facility for tempering and hardening upon sudden cooling in water.

With modern methods, steel is produced by reducing the carbon percentage of cast iron to the desired amount. This may take place in two ways by:

1. Bessemer process.
2. Open hearth process.

Bessemer Process.—This process consists in blowing air into a vertical, pear shaped converter, full of molten cast iron. The air is blown in at the bottom, and rising through the molten mass burns the carbon. If the air admission be arrested at the right time a steel of predetermined quality and hardness may be obtained.

The converter is tripped on trunnions and its contents poured into moulds.

The ingots coming from these moulds are then rolled into plates or shapes, or forged out as required.

Bessemer steel is objected to by some engineers, as not possessing uniformity of qualities throughout the material obtained from the same converter. Further, it is not always possible to determine the exact point at which to arrest the admission of air, with consequent uncertain results.

Open Hearth Process.—In this method cast iron is deprived of its surplus carbon in a shallow furnace, where the molten material is exposed, on a broad surface, to passing currents of air and gases, which burn out the carbon.

The molten mass can be mixed and stirred, and, by removing a small amount as a sample, can also be tested. By this means the reduction of carbon can be more accurately adjusted to the desired degree. The open hearth product is regarded by many engineers as nearer uniform in qualities and therefore preferable for most purposes.

Iron and Steel Definitions.—At the Brussels Congress of the International Association for Testing Materials, held in September, 1906, the following definitions of the most important forms of iron and steel were adopted:

DEFINITIONS

Alloy cast irons.—Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy steels.—Steels which owe their properties chiefly to the presence of an element other than carbon.

Basic pig iron.—Pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open hearth process (restricted to pig iron containing not more than one per cent of silicon).

Bessemer pig iron.—Iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than $1/10$ per cent of phosphorus).

Bessemer steel.—Steel made by the Bessemer process, irrespective of carbon content.

Blister steel.—Steel made by carburizing wrought iron by heating it in contact with carbonaceous matter.

Cast iron.—Iron containing so much carbon or its equivalent that it is not malleable at any temperature. The committee recommends drawing the line between cast iron and steel at 2.2 per cent carbon.

Cast steel.—The same as crucible steel; obsolete, and confusing; the terms "crucible steel" or "tool steel" are to be preferred.

Converted steel.—The same as blister steel.

Charcoal hearth cast iron.—Cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

Crucible steel.—Steel made by the crucible process, irrespective of its carbon content.

Gray pig iron and gray cast iron.—Pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the color of graphite.

Malleable castings.—Castings made from iron which when first made is in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Malleable iron.—The same as wrought iron.

Malleable pig iron.—An American trade name for the pig iron suitable for converting into malleable castings through the process of melting-treating when molten, casting in a brittle state, and then making malleable without remelting.

Open hearth steel.—Steel made by the open hearth process irrespective of its carbon content.

Pig iron.—Cast iron which has been cast into pigs direct from the blast furnace.

Puddled iron.—Wrought iron made by the puddling process.

Puddled steel.—Steel made by the puddling process, and necessarily slag bearing.

Refined cast iron.—Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Shear steel.—Steel, usually in the form of bars, made from blister steel by shearing it into short lengths, piling, and welding these by rolling or hammering them at a welding heat. If this process of shearing, etc., be repeated, the product is called "double shear steel."

Steel.—Iron which is malleable at least in some one range of temperature and, in addition, is either 1, cast into an initially malleable mass; or 2, is capable of hardening greatly by sudden cooling; or 3, is both so cast and so capable of hardening.

Steel castings.—Unforged and unrolled castings made of Bessemer, open hearth, crucible, or any other steel.

Washed metal.—Cast iron from which most of the silicon and phosphor have been removed by the Bell-Krupp process without removing much of the carbon, still contains enough carbon to be cast iron.

Weld iron.—The same as wrought iron; obsolete and needless.

White pig iron and white cast iron.—Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought iron.—Slag bearing, malleable iron, which does not harden materially when suddenly cooled.

In addition to these definitions, others will be found, being terms used in testing and representing the behaviour of materials under tests.

Copper.—This is a common metal of a brownish red color, both ductile and malleable and very tenacious. It is one of the best conductors of heat and electricity. It is one of the most useful metals in itself, and also in its various alloys, such as brass and bronze. It is the only metal which occurs native, abundantly in large masses; it is found also in various ores, of which the most important are *chalcopyrite*, *chalcocite*, *cuprite* and *malachite*. Mixed with tin, it forms bell metal, with a smaller proportion, bronze; and with zinc, it forms brass, pinchbeck and other alloys.

The strength of copper decreases rapidly with rise of temperature above 400° F.; between 800° and 900° its strength is reduced about half that at ordinary temperatures. Copper is

Fig. 5,991.—Ingot copper; weight 6 lbs.

not easily welded, but may be readily braized. At near the melting point it oxidizes or is *burned* as it is called and loses most of its strength, becoming brittle when cool.

Brass.—This is a yellow alloy composed of copper and zinc in various proportions. In some grades tin or lead in small amounts is added. Brass is used largely for steam and plumbers fittings, electrical devices, builders' hardware, musical instruments, etc.

When zinc is present in small percentages the color of brass is nearly red; ordinary brass for piping, etc., contains from 30% to 40% of zinc. Brass can be readily cast, rolled into sheets, or drawn into tubes, rods and wire of small diameter.

The composition of brass is determined approximately by its color: Red contains 5% of zinc; bronze color, 10%; light orange, 15%; greenish yellow, 20 ; yellow, 30%; yellowish white, 60%. The so called low brasses contain 37 to 45% of zinc and are suitable for hot rolling, and the *high* brasses contain from 30 to 40% of zinc, being suitable for cold rolling.

Varieties of Modern Brass

Name or Color	20 per cent Cupro Manganese	Copper	75 per cent Aluminized Nickel	5 per cent Ferro-Zinc	30 per cent Aluminized Zinc	Zinc	Tin	Lead	Metallic Phosphoro
Red Brass	....	93.75	....	....	....	6. ..	....	....	.25
" "	....	90.75	....	....	....	7. ..	....	2.	.25
" "	....	86.75	....	....	....	7.50	2.50	3.	.25
Reddish Yellow Brass..	....	87.75	....	....	....	11. ..	....	1.	.25
Yellow Brass	....	81.75	....	....	....	18. ..	....	....	.25
Bright Yellow Brass...	....	72.75	....	....	....	27. ..	....	....	.25
Full Yellow Brass......	....	70.75	....	....	....	24. ..	2.	3.	.25
" " "	....	66.75	....	15.	....	17. ..	1.	....	.25
" " "	....	64.75	....	....	....	33. ..	....	2.	.25
" " "	....	60.75	....	....	....	39. ..	....	....	.25
Light Yellow Brass....	....	55.75	....	20.	....	24. .	....	....	.25
" " "	....	50.75	....	25.	....	24. .	....	....	.25
White Brass	....	39.75	....	....	....	60. ..	....	....	.25
" "	....	30.75	....	....	....	69. ..	....	....	.25
" "	....	10.	....	....	10.	75. ..	4.	....	1.
Aluminum Brass	....	79.75	....	....	20.	....	....	....	.25
" "	....	69.75	....	....	30.	....	....	....	.25
" "	....	59.75	....	....	40.	....	....	....	.25
" "	....	53.	1.75	45.	....	....	....	....	.25
" "	....	72.	2.75	....	25.	....	....	....	.25
" "	....	81.	3.75	....	15.	....	....	....	.25
Manganese Brass	1.75	75.	....	....	2.	16.	5.	....	.25
" "	2.75	70.	....	....	3.	20.	4.	....	.25
" "	3.75	65.	....	....	4.	24.	3.	....	.25
" "	4.75	60.	....	....	5.	28.	2.	....	.25

Cast Iron.—The properties of cast iron depend chiefly on the proportion of total carbon, and in the relative proportion of combined carbon and graphite.

Soft cast iron called *gray* iron contains a high percentage of

graphite which renders it tough, with low tensile strength; it breaks with a coarse grained dark or grayish fracture.

The iron becomes more brittle and harder as the relative percentage of combined carbon and graphite decreases; its tensile strength increases somewhat, and the fracture is fine grained or smooth. This grade of iron is called *white* iron.

Mottled iron is that grade in which half the carbon is combined and half separates out as graphite. In casting, when cast iron hardens, it expands
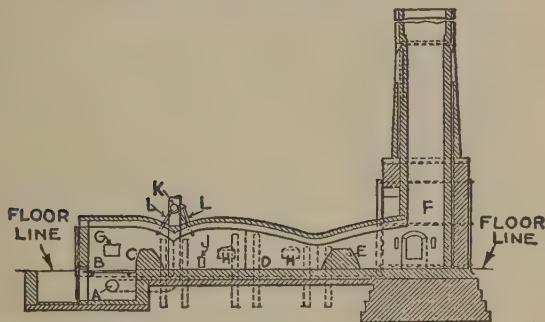
Fig. 5,992.—Air furnace for melting iron to be used for malleable castings. A blast for the pipe A, passes through the fuel bed B, over the bridge wall C, to the metal on the refractory bed D, then over the bridge wall E, into chimney F. The door G, gives access to the fuel bed and the doors H, to the molten iron, which is drawn off through the tap J. Frequently air pipes are placed in the first bridge wall C, so as to add air to the flames, slightly improving the combustion. In the furnace shown the auxiliary air is furnished by a pipe K, running across the top of the furnace and feeding a number of small pipes L, that supply the air near the bridge wall so as to obtain the greatest combustion just over the lapping spout. Sometimes the lapping spouts are placed at different levels so that the hottest metal can be drawn off first, thus preventing its burning as well as making the composition of the casting nearer uniform. The heating of the bath is aided by the arched roof, which deflects the heat toward the molten metal. The bath should be deepest by the bridge wall C, and slope upward toward the bridge wall E. To avoid burning the metal here, the metal should be 2 or 3 inches deep instead of having a feather edge; the coming of slag then will prevent excessive oxidation of the metal.

and then contracts as it cools, the shrinkage being about $\frac{1}{8}$ inch per foot in all directions. Hardness and shrinkage increase or decrease together.

In boiler construction cast iron is used for grate bars, furnace door frames and minor boiler fittings.
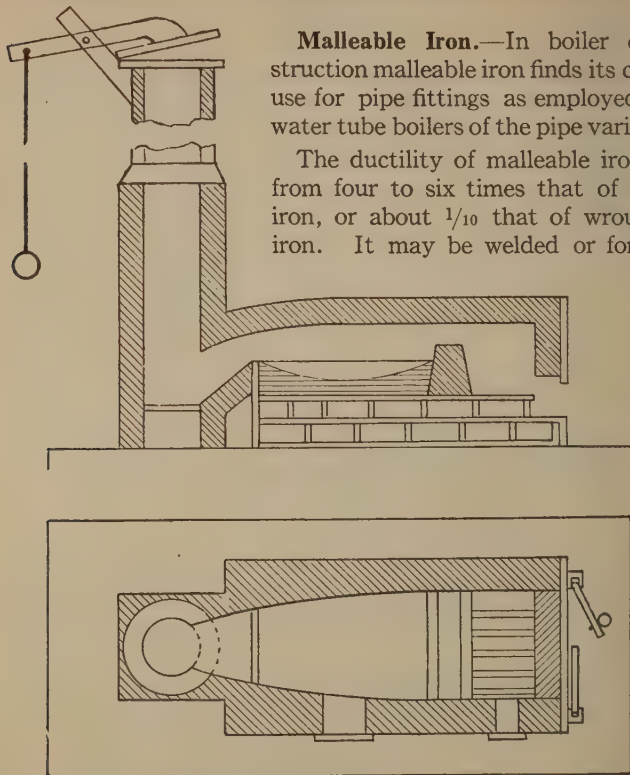
Malleable Iron.—In boiler construction malleable iron finds its chief use for pipe fittings as employed in water tube boilers of the pipe variety.

The ductility of malleable iron is from four to six times that of cast iron, or about $1/10$ that of wrought iron. It may be welded or forged

Figs. 5,993 and 5,994.—Puddling furnace capacity usually from 1,000 to 6,000 pounds of iron. The fire place is rectangular and is separated from the bath by a low bridge wall. The roof is arched and slopes toward the flue which causes the flames to beat down upon the metal. The air supply is regulated by the damper at the top of the stock, forced draught being used The bridge work overlaps the tops of the side frames, so as to form a recess for the *fettling* or *fix* with which it is lined. This fettling is a mixture of oxide of iron and sand from the bottom of the hearth. Under the great heat generated in the furnace, some of this sand melts with the pig iron and forms what is called a bath in which the puddling process is carried on. The silica in the sand unites with the iron and makes a slag, which protects the iron from oxidizing so that large sized puddle balls can be made. A large percentage of slag is worked out in the further refining which the metal receives.

with proper care and can be case hardened. Good malleable iron will stand considerable bending and twisting before breaking.

Steel.—By mixing with steel certain other metals, mainly manganese, nickel, aluminum, chromium and tungsten, its strength, hardness or toughness may be increased as desired.
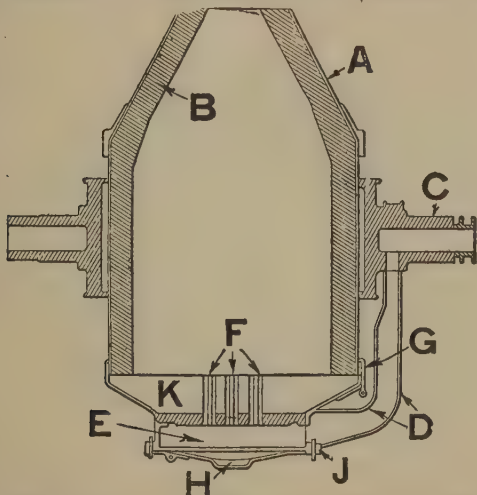
FIG. 5,995.—Bessemer converter. *It consists of* a large steel shell A, lined with a refractory material B, and turning on trunnions C. Air entering through one trunnion passes through the pipes D, and the tuyere or wired box E, into the converter through the tuyeres F. A refractory bottom K, is fastened to the shell by the key link G, and the lid H, is fastened to the tuyere box by the key J. As the lining corrodes rapidly around the tuyeres, the bottom is made easily removable for quick replacement with a new one.

The first essential of boiler plate is a uniform blending of the physical properties that will enable the material to recover from the strains induced by the various stresses of operation.

The most important of these properties is tenacity, or ability to resist a pulling stress.

Carbon possesses no great strength on its own account, but when joined in chemical affinity with iron it develops strength therein. Correct proportions must be maintained, however, Increasing the carbon content up to a certain per cent. conduces to strength; beyond this point the strength deteriorates.

Mild steel that contains .1 per cent. of carbon, for example, has a tensile strength of about 50,000 pounds per square inch, while 12 times this quantity, or 1.2 per cent., increases the tenacity to nearly 140,000 pounds per sq. in., which is probably the limit for carbon steel.
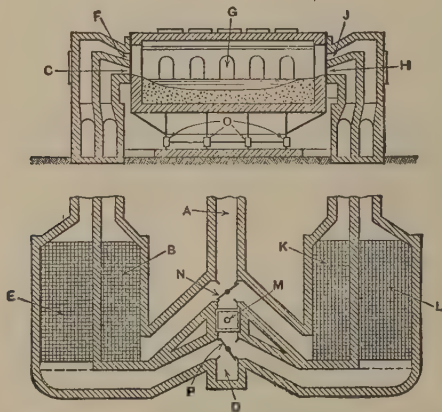
Figs. 5,996 and 5,997.—Open hearth furnace and plan of regenerative chambers and flues. Usual capacity 50 to 60 tons. ***It consists of*** a rectangular hearth with ports at each end through which the gas enters and leaves. Two chambers at each end provide means for heating the air and the gas. The roof of the furnace must be high enough so that it will not be burned up by an impinging flame from the ports. The hearth must be of such a length that there will be complete combustion; its length should be about 2 to 2½ times its width; and its depth sufficient to permit oxidation of the metal, yet shallow enough to give thorough heating and reasonably quick working of the bath.

Increasing the percentage of carbon above this figure causes a proportionate drop in the tenacity of the steel.

With 2 per cent., its strength is about 90,000 pounds.

A further gradual increase of the carbon component causes the material to rapidly acquire the characteristics of cast iron.

Phosphorus enhances the strength of steel. It also adds to the hardness of the plate and thus makes it better able to resist abrasion. These qualities are, however, best secured through the medium of carbon, because phosphorus tends to make the material brittle. Steel containing much phosphorus is particularly weak against shocks and vibratory strains. On this account it may be considered the most harmful impurity in steel boiler plate.

Sulphur increases the brittleness of steel while hot, making it "red short," and interfering seriously with the shaping and forging of the material. It should not exceed from .02 to .05 of one per cent.

Manganese increases the strength, hardness and soundness of the
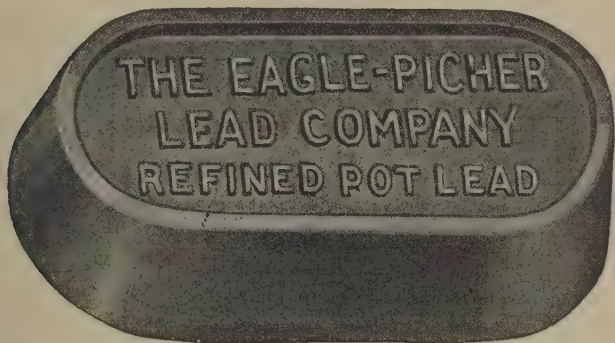
Fɪɢ. 5,998.—Refined pot lead, cast in cakes weighing 4 lbs. each.

steel. Steel containing a considerable proportion of this element acquires a peculiar brittleness and hardness that makes it difficult to cut. Manganese has, however, a neutralizing effect on sulphur.

Nickel increases both the strength and toughness of the steel.

Aluminum acts upon steel largely in the direction of improving the soundness of ingots and castings.

Lead.—When plumbing was plumbing (see fig. 5,999), lead was the all important material, but it has since been largely replaced by other metals. Lead may be described as a bluish

gray metal with a bright lustre when melted or newly cut. It is the heaviest of all common metals, and weighs .4106 lbs. per cu. in.

Atomic weight 206.9.

Specific gravity 11.37 (Reichs) for pure lead at 0° C. (water at 4° C. being unity) Roberts-Austen gives as specific gravity of solid lead 11.40 of liquid lead 10.65 and 10.67. The specific gravity will vary slightly according as it is cooled quickly or slowly, hammered or rolled.

Commercial lead has a lower specific gravity than 11.37 on account of the impurities contained in it.
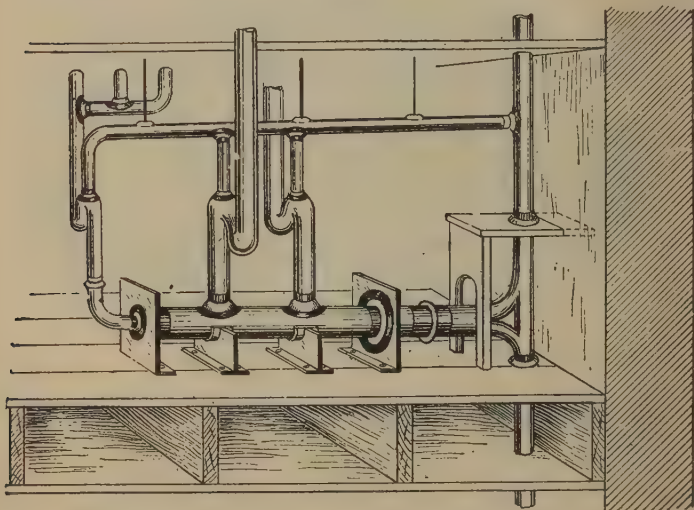
FIG. 5,999.—When plumbing was plumbing, showing an all lead installation.

Breaking strength in tons per sq. in. (cast) lead .81, sheet lead .86, lead pipe 1.00.

Average crushing load per sq. in. (cast) 7,350 lbs.

Tensile resistance 2,240 lbs.

The safe working strength of lead is about ¼ the elastic limit or 225 lbs. per sq. in.

Lead is very soft, especially when allowed to cool and solidify slowly.

Lead is very malleable and ductile.

Fracture of lead is hackly when broken cold, columnar when hot.

Lead is readily dissolved in water containing carbonic acid or salts of nitric acid; the solution is poisonous.

Linear coefficient about ⅓ of the cubical.

Heat conducting power of lead is about 85.   (Weidemann & Franz.)

Lead absorbs in fusing 5.4 metric thermal units per kilogram.

Specific heat between 10° and 100° C. is .0314, with silver as 100, the conductivity for heat at 12° C. is 8.5 and for electricity, 10.7.
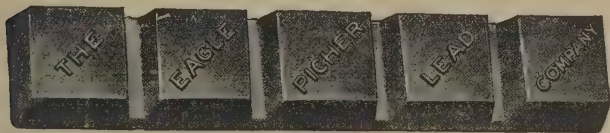
FIG. 6,000.—Refined ingot lead, cast in notched bars weighing 9 lbs. each.

Latent heat of lead is 5.369.

Lead does not crystallize readily.   When refined lead is poured at the correct temperature into a warm mould and allowed to cool, fern-like crystalline aggregates appear at the surface.   In the form of filings it becomes according to Roberts-Austen a solid mass if subjected to a pressure of 13 tons per sq. in., and liquifies at $2^1/_2$ times this pressure.

Lead undergoes no change in dry air nor in water that is free from air. Lead becomes pasty at about 617° Fahr. and melts at about 650°.   It boils at about 1500° C. but cannot be distilled; its coefficient of linear expansion at ordinary temperatures by heat for 1° Fahr. is .00001571.

Shrinkage of lead castings is $^5/_{16}$ in. per foot.

The strength of lead in both compression and tension is very small As lead unites readily with almost all other metals, it is used in many alloys for bearing metals, solders, etc. Alloys composed of lead, bismuth and tin are noted for their low melting points.

Effects of Acid on Lead.—In the use of lead as a material the following effects of various acids should be noted.

Sulphuric Acid.—The purer the lead the less will it be attacked by pure or nitrous sulphuric acid up to 200° C., the highest temperature employed under normal conditions in concentrating pans. Above 100° C. the action becomes stronger and at 260° C. the lead is dissolved. Concentrated nitrous sulphuric acid acts at all temperatures more powerfully than pure sulphuric acid, and the effect is greater in the presence of air. Dilute nitrous sulphuric acid of a specific gravity of 1.72-1.76 is not as powerful as the pure acid, although if the dilution be continued beyond this point the power increases again instead of diminishing. Boiling sulphuric acid of sp. gr. 1.84 acts severely on lead and fuming acid more so.

Jounge found that a rough surface was more readily corroded by nitrous sulphuric acid than a smooth surface; and the greater the content of nitrogen oxides in the acid the more the lead is attacked.

Organic Acids.—Acetic, tartaric and citric acids attack lead in contact with air.

Nitric Acid dissolves lead, forming nitrate of lead. This acid acts very energetically when diluted, but more slowly when concentrated owing to the nitrate of lead being insoluble in strong nitric acid.

Hydrochloric Acid has practically no action on lead. Boiling concentrated hydrochloric and sulphuric acid of 66° B, dissolve it slowly.

Aqua Regia converts lead into a chloride.

Arsenic and Arsenious Acids react with lead, yielding arsenate or arsenide of lead.

Peat Acids in water rapidly dissolve lead.

Chlorate of Potash dried upon lead covered tables will be found to contain traces of lead.

Gases of a properly worked sulphuric acid plant have a very mild action upon the sheet lead of which the chambers are built, and when any severe action takes place some abnormal condition is sure to have been the cause.

Chlorine does not attack lead to any serious extent; but when chlorine is accompanied by traces of hydrochloric gas the damage is often extensive.

Lime Wash upon lead after having dried helps chlorine to form the purple oxide of lead. This shortens the life of lead, and should not be used on the outside of bleaching powder chambers.

Lead Poisoning.—Lead is a poisonous metal and accordingly the following precautions should be taken in working with lead to guard against danger of poisoning.

1. Wash your hands carefully before eating, or taking tobacco or handling anything that will be placed in the mouth.

2. Always rinse out your mouth before taking a drink.

3. After having been in the dust or fumes, spit a few moments thereafter and rinse out your mouth at the first opportunity.
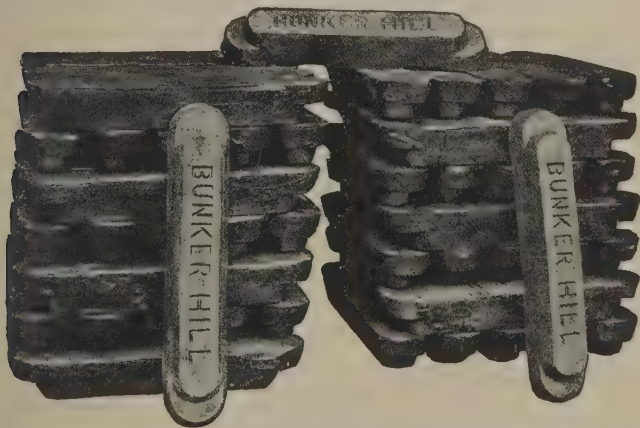
FIG. 6,001.—"Bunker hill hard" pig lead. The term *pig* means the metal as cast into bars at the conclusion of the process of smelting. The manufacturer claims the lead is refined to 99.99% pure. In using a lead refined to this degree, the danger of cracking the soil pipe hub when pouring the molten lead is avoided. There is danger of cracking when scrap lead has been used. The pigs as shown weigh about 100 lbs. each. Antimonized pig lead is also produced in pigs weighing about 90 lbs. each.

4. Bathe frequently.

5. Either change your clothing before going to work, or put on outside overalls and jumper while at work. This outside clothing should be washed as frequently as possible.

6. When passing to the leeway of fumes, hold your breath as much as possible. Pass to the windward as much as possible. Where fumes or dust are abundant, tie a handkerchief over your mouth and nose.

7. Never come to work without having eaten a substantial meal. With an empty stomach, conditions are more favorable for absorption of lead by the body.

8. Drink water and milk plentifully.

9. Do not allow yourself to become constipated.

10. Put a little plain vaseline in your nose at the beginning of your shift.

11. If you feel at all sick, consult a doctor at once.

12. Do not keep your mouth open when breathing; breathe through your nose.

13. The use of tobacco and of tea and coffee make one more sensitive of lead; milk makes one less sensitive.

Tin.—This is a soft metal, the color being white with a tinge of yellow. It has a high lustre, hence is frequently used as reflectors of light. Tin when nearly pure has a specific gravity of 7.28 to 7.4, the pure tin is the lightest. It has a low tenacity but is very malleable and can be rolled or laminated into very thin sheets, known as tin foil.

The melting point of tin is 443° Fahr.

At 212° (the boiling point of water) it is ductile and easily drawn into wire. It boils at white heat.

It burns with a brilliant white light when raised to a high temperature and exposed to the air.

Its specific heat is .0562; latent heat of fusion, 25.65 B.t.u. per lb.

Conductivity is low. Oxidizes slowly in the air at ordinary temperatures when exposed to extreme cold, tin becomes crystalline. Heat conductivity 14.5, electric conductivity 12.4, compared with silver = 100 in each case.

Its weight is 459 lbs. per cu. ft.

Tensile strength 3,500 lbs. per sq. in.; crushing load (cast tin) 15,500 lbs. per sq. in.

Owing to its high power of resistance to tarnishing by exposure to air and moisture, tin is much used as a protective coating for iron and copper, and for lining lead pipes that are used for conveying soft drinking water.

Diluted sulphuric acid has no action on tin when cold, but when boiled in concentrated acid the metal is dissolved. Coefficient of expansion of tin is .0000151 per 1° Fahr.

The principal use of tin by plumbers is for alloying with lead to make solders. Sheet tin (erroneously so called) is sheet iron coated with tin. See page 1,239.

Antimony.—This metal is hard, brittle and resembles tin in its fracture. It crystallizes in the hexagonal system and its
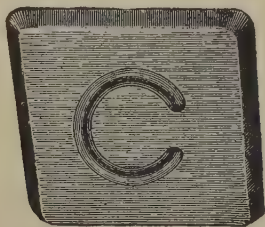
Fig. 6,002.—Antimony in cakes; weight 30 to 50 lbs. each.

color resembles tin more than lead. Specific gravity is between 6.6 and 6.8 and melting point 810 to 842° Fahr. (authorities differ on melting point). Boiling point between 1090 and 1450° Cent. Specific heat at ordinary temperatures, .0508.

Conductivity for heat (silver being 1,000) along axis of crystallization is 215, and at right angles to this is 193.

Conductivity of electricity at 18.7° C. (silver being 100) is 4.29.

Antimony is used as a hardening ingredient in lead and tin alloys, such as Babbitt and various other so called anti-friction metals.

Bismuth.—This very brittle crystalline metal is of a grayish white color tinged with pink or red. The native metal is its most important source, as found in Cornwall, Saxony, Norway, etc., but bismuth is often found in combination with ores of silver, cobalt, zinc and lead.

Its specific gravity is from 9·6 to 9·8, the melting point is 507° F. and it volatilizes at a white heat.

It is a remarkable metal for two properties; its specific gravity decreases under pressure, and it expands on cooling.

Various compounds of bismuth with other metals melt at points below that of boiling water, *Wood's metal,* of 4 bismuth, 2 lead, 1 tin, 1 cadmium (all by weight) melts and remains fluid at 142° Fahr.

Fig. 6,003.—Zinc or spelter in large slabs, weighing about 35 lbs. each. Small 4 ×8 in. slabs weigh about 4 lbs. each.

Bismuth is used in many alloys under the name of expansion metal, and in making solder for tin pipe.

Zinc.—A hard bluish white metal with a crystalline fracture; appears as if it were composed of plates adhering together. Zinc in the form of ingots is called *spelter;* it is quoted by this name in metal market reports and in business transactions. It is brittle at ordinary temperatures; between 212° and 300° Fahr. it is ductile and malleable and at 410° it again

becomes brittle.   It melts at 773°, boils at 1900° and volatilizes at a bright red heat; when it burns, it forms zinc oxide.

The tenacity of zinc is 5,000 to 6,000 lbs. per sq. in., or about $1/_{10}$ that of wrought iron.

Specific gravity 7.04. Zinc weighs .2526 lbs. per cu. in., or 436.5 lbs. per cu. ft. Zinc tarnishes when exposed to moist air and is corroded when in contact with soot and moisture. It is easily attacked by mineral acids.

When zinc is used for lining cisterns or for coating iron water pipes or sheet iron for making cisterns, and the water which it comes into contact with is soft and contains a slight acid, the metal is gradually corroded or eaten away.

When rolled into thin sheets, zinc is largely used for roofs on account of lightness; also used for eaves, gutters, leaders, etc. Zinc should not be used for soil pipes.

"Babbitt's Metal."—This is an alloy of tin, antimony and copper, discovered in 1839 by a goldsmith of Boston, named Isaac Babbitt. The United States granted Babbitt $20,000 for the right to use his formula in government work, and the Massachusetts Charitable Mechanics Association awarded him a gold medal in 1841. Babbitt's formula is a good one, and is still the standard with the United States Government and many of the largest manufactories in the country. Unfortunately, competition and high priced materials have encouraged adulteration, and the genuine formula is not always followed unless the alloy is subject to chemical analysis.

Babbitt Metals (not Babbitt's metal) cover a wide range of alloys of uncertain composition and are frequently made to meet the price offered, without regard to their wearing qualities, or the work for which they are to be used. There are two ways to make Babbitt metals, one with tin for a base, and the other with lead for a base. All cheap metals have lead for a base. All high grade metals have tin for a base.

Tin base metals are cheapened and their wearing qualities reduced by adding lead. Adding tin to lead base metals improves their appearance, increases their cost, and adds to their wearing qualities. Tin base metals if free from lead should weigh about $4\frac{1}{2}$ ounces per cubic inch. Lead base metals, if free from tin, weigh about 6 ounces per cubic inch. It is important to know the weight per cubic inch in comparing prices of different grades of Babbitt metals.

High grade metals are generally made of new materials. Cheap metals are usually made of lead drosses.

It is frequently the case that loss of time and cost of labor rebabbitting bearings amount to more than the price of the metal used. A metal costing twice as much if it wear only twice as long is less expensive to use than a cheaper metal, but the high grade metal may wear five times as long.

How to Use Babbitt Metals.—In using Babbitt metals, they should be melted slowly and only to a temperature that will insure their flowing freely, except in some compositions having a content of zinc, such as white brass or white bronze.

They should not be mixed with other metals, of unknown composition.

A high grade metal will not improve a cheap metal as much as the cheap metal will depreciate the high grade metal.

The bearing should be ready for pouring before the metal is melted.

A little granulated sal-ammoniac on the surface of the molten metal makes it more fluid and gathers whatever dross may be in it.

Oxidized or thickened metal may be recovered by adding it in small quantities to new metal of the same kind.

Covering the journal with French chalk (gypsum), makes the metal flow freely and prevents sticking.

Warming the journal before pouring insures against moisture and avoids chilling the metal.

When molten metal will char a dry pine stick it is ready to pour, but the metal should not be hot enough to start a flame.

The following formulæ for various Babbitt metals will be found of value and can be depended upon to produce satisfactory results.

Varieties of Modern Babbitts

Reference Numbers	75 per cent Aluminized Nickel	Copper	Antimony	30 per cent Aluminized Zinc	Tin	Lead	Cadmium	Metallic Phosphoro
1	....	....	12.	....	....	85.	....	3.
2	....	....	15.	....	....	82.	....	3.
3	....	....	18.	....	....	78.	....	4.
4	....	....	15.	....	5.75	76.	....	3.25
5	....	....	12.50	....	15.	70.	....	2.50
6	....	....	10.	....	25.	61.	....	4.
7	....	....	8.	....	45	41.	....	6.
8	....	4.	6.	....	86.	....	....	4.
9	....	6.	6.	....	82.	....	....	6.
10	1.50	3.50	....	7.	87.	....	....	1.
11	3.	2.	....	5.	88.	....	1.	1.
12	4.	....	....	3.	90.	....	2.	1.
13	....	7.	5.	....	83	....	....	5.
14	....	2.	10.	....	20.	66.	....	2.
15	....	3.	9.	....	30.	55.	....	3.
16	....	4.	8.	....	40.	44.	....	4.
17	....	5.	7.	....	50.	33.	....	5.
18	....	6.	6.	....	60.	22.	....	6.

Aluminum.—This metal is of a silvery white color and is not corroded by atmospheric influences or fresh water, also resisting nitric acid, but is decomposed by alkalies, in sea water, and by dilute sulphuric acid; it is malleable, ductile and sonorous, also a good conductor of heat and electricity. It is the lightest of all useful metals except magnesium. Its tenacity is about $\frac{1}{3}$ that of wrought iron. Melts at 1215° Fahr and does not volatilize at any temperature produced by the combustion of carbon. Specific heat .2185. Specific gravity 2.67; weight .0963 lb. per cu. in., 166.5 lbs. per cu. ft.

Aluminum can be readily electrically welded but soldering is not altogether satisfactory.

Oakum.—This consists of shredded rope or hemp fibre made together by moistening it with pine tar. It can be obtained in bales either loose or slightly twisted and is used as a packing material.

Asphaltum.—The name asphaltum is given to a water-proofing paint made for asphalt. Asphalt is black or dark brown in color and melts or burns, leaving no residue. It dissolves in petroleum or turpentine.

In making waterproof paint it is mixed with coal tar and

FIG. 6,004.—Aluminum in bars; weight 1 lb. each.

put on hot. Used for coating pipes, etc., exposed to dampness. In applying the surface to be painted should be heated to the melting point of the asphalt.

Plumbers' Portland Cement Mortar.—The Portland cement should be mixed with an equal part of clean sharp sand and then tempered with clean water into a thick mortar. Mix only as used as it quickly sets. It is used for many purposes, especially for jointing earthenware pipes. This cement will set with water.

Glaziers' Putty.—Made by mixing 7 parts whiting with 3 parts (by weight) of boiled linseed oil. It is used for bedding woodwork around fixtures and for bedding cast iron sinks, etc.

Red Lead.—On passing an air blast over the surface of molten metallic lead, the metal absorbs oxygen from the air and is converted into *litharge*. This oxide is ground into a fine powder and reheated a second time, when it absorbs more oxygen, becoming, when cool, a bright scarlet or orange powder, known as *red lead*. It has a powerful drying action on oil, possesses good covering properties as a paint and may be mixed with other colors.

It is prepared for use by mixing it with boiled linseed oil just before using. It becomes very hard in setting and when used on upright pipe will make tight joints but joints that will be difficult to unscrew. Red lead is also used to bed fixtures, set slabs, etc.; it should not be used to joint marble work as the marble will be stained by the oil.

White Lead.—A mixture of lead carbonate and hydrated oxide; used as paint and in cements. Lead buckles, discs about 7 inches diameter and ½ inch thick are placed in earthenware pots, 14 or 15 ins. high, with acetic acid. The pots are stacked up into bins, some 40 ft. square, and covered with spent tan bark, the whole being left for three months. Steam is given off and a complex chemical action takes place, some 60 to 65 per cent. of the lead being turned into white lead, which is separated by a centrifugal machine, the unchanged lead being remelted, and worked over again. The white lead is ground to powder, and reground to a paste with ten per cent. of linseed oil.

White lead is used by plumbers for the same purposes as red lead.

Plumbers' Soil.—This consists of lamp black mixed with a small amount of glue and water. It is used around parts to be soldered to prevent the adhesion of the solder except to its proper place, thus giving a neat and finished appearance.

Brick.—Clay bricks expand or shrink, depending upon the proportion of silica to alumina contained in the brick, but most fire clay brick contain alumina sufficient to show some shrinkage. A straight 9 inch fire brick weighs 7 pounds, a silica brick 6.2 pounds; a magnesia brick, 9 pounds; a chrome brick, 10 pounds. A silica brick expands about $\frac{1}{8}$ inch per foot when heated to 2,500° F.

Pipe Coverings or Insulators.—According to Kent asbestos
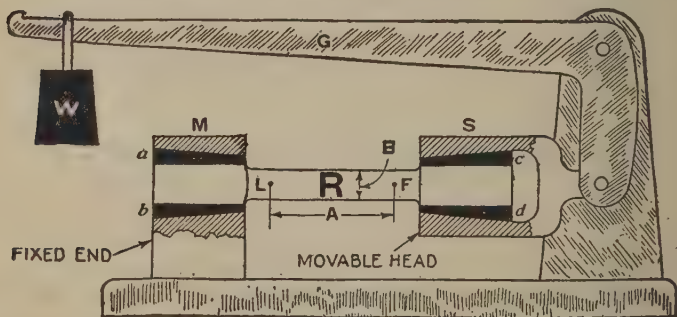
Fig. 6,005.—*Tensile test.* The specimen R, is placed in the wedge grips *a, b, c, d,* thus pulling it in tension between the fixed end and movable head of the machine. The latter is connected with the scale lever G, upon which sides the weight W, similar to an ordinary weighing scale. Two center marks L and F, are punched on the specimen at a standard distance A, apart. *In testing,* the pull on the specimen is gradually increased by moving W, to the left and the dimensions A, and B, measured for each increase of load.

is one of the poorest insulators. It may be used to advantage to hold together other incombustible substances, but the less of it, the better.

Any covering should be not less than one inch thick. A covering should be kept perfectly dry, because still water conducts heat about eight times quicker than still air. Some good coverings arranged in order of efficiency (the most efficient first), are: Rock wool, mineral wool, magnesia, hair felt, fire felt.

Tests.—The strength of the materials used in construction is best determined by tests.

Metals are tested for strength in various ways as by taking a sample of standard shape and subjecting it in testing machines to tension, compression, bending, sheering stresses. There are various terms used in testing and the definitions, as here given, should be carefully noted.
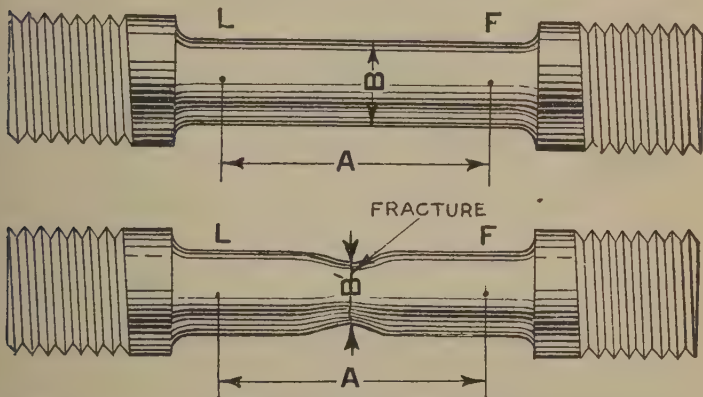
FIGS. 6,006 and 6,007.—Tensile test specimen before and after rupture showing reduction of section B, at break. *Example,* Assume A = 2 inches; B = .505 inches then cross area of specimen before test = .2 square inch; this value is used in calculating elastic limit and ultimate strength. Now if the loads be 6,250 and 12,160 pounds, then 6,250 ÷ .2 = 31,250 pounds elastic limit per square inch, and 12,160 ÷ .2 = 60,800 pounds ultimate strength per square inch. To calculate the percentage of elongation, the broken parts are placed together and A' measured. Assuming A' = 2.55 inches, then 2.55—2 = .55 in total elongation, and 55 ÷ 2 × 100 = 27½ per cent elongation. Again using micrometer, assume B' to measure .346 inch, then area = .094 inch, and .2—.094 = .106 square inch total reduction of area from which .106 ÷ .2 × 100 = 53 per cent reduction of area.

DEFINITIONS

Bending stress.—In physics, a force acting upon some member of a structure tending to deform it by bending or flexure; the effect of this force causes bending *strain* on the fibers or molecules of the material of

which the part is composed. An instance of pure bending stress is given by pulling on the end of a lever, which tends to deflect it while performing work.

Compression.—To press or push the particles of a member closer together, as, for instance, the action of the steam pressure in a boiler on the fire tubes.

Deformation.—Change of shape; disfigurement, as the *elongation* of a test piece under tension test.

Factor of safety.—The ratio between the *breaking load* and what is selected as the *safe working load*. Thus, if the breaking load of a bolt be

FIG. 6,008.—*Compression test.* The specimen R, is placed between the two plates M, and S, and a compression stress of any intensity applied by moving the weight W, on the lever G. *In testing,* as the load is gradually increased, the changes in dimensions A, and B, are noted and result calculated in a manner similar to that explained for the tension test fig. 6,005.

60,000 *pounds per square inch*, and the working load be 6,000 *pounds per square inch*, then the factor of safety is 60,000 ÷ 6,000 = 10.

Force.—That which changes or tends to change the state of a body at rest, or which modifies or tends to modify the course of a body in motion, as a *pull* pressure or a *push*; a force always implies the existence of a simultaneous equal and opposite force called the *reaction*.

Load.—The total pressure acting on a surface; thus, if an engine piston having an area of 200 square inches be subjected to a steam pressure of 150 pounds *per square inch*, then the load, or total pressure on the piston is 200 × 150 = 30,000 pounds.

Member.—A part of a structure as a brace, rivet, tube, etc., subject to stresses.

Modulus (or Coefficient) of elasticity.—The load per unit of section divided by the elongation or contraction per unit of length. Within the elastic limit, when the deformations are proportional to the stresses, the modulus of elasticity is constant, but beyond the elastic limit it decreases rapidly. In wrought iron and steel there is a well defined elastic limit, and the modulus within that limit is nearly constant.

Modulus of Rupture.—A value obtained by experiment upon a rectangular bar supported at the ends and loaded at the middle, substituting results in the formula

$$R = \frac{3\,Pl}{2\,bd^2}$$
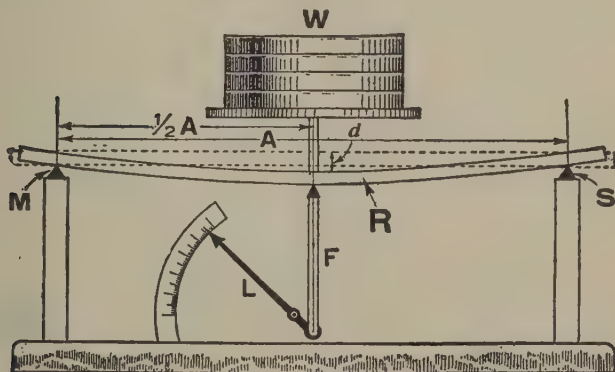
Fɪɢ. 6,009. —*Transverse test.* The specimen R, is placed on two supports M, and S, and a load W, applied at the mid-point as shown. The deflection or amount of bending for any load is indicated with precision by the multiplying gear LF. *In testing,* the weight W, is gradually increased and deflections noted till the breaking load is reached.

in which P = breaking load in pounds; *l*, *b*, and *d* = length, breadth and depth respectively in inches.

Permanent set.—When a metallic piece is stressed beyond its elastic limit, deformation occurs, the piece being either stretched, crushed, bent or twisted, according to the nature of the strain. This alteration in form is known as *permanent set.*

Resilience.—The property of springing back or recoiling upon removal of a pressure, as with a spring. Without special qualifications the term

is understood to mean the work given out by a spring, or piece, strained similarly to a spring, after being strained to the extreme limit within which it may be strained again and again, without rupture or receiving *permanent set*.

Shear.—The effect of external forces acting so as to cause adjacent
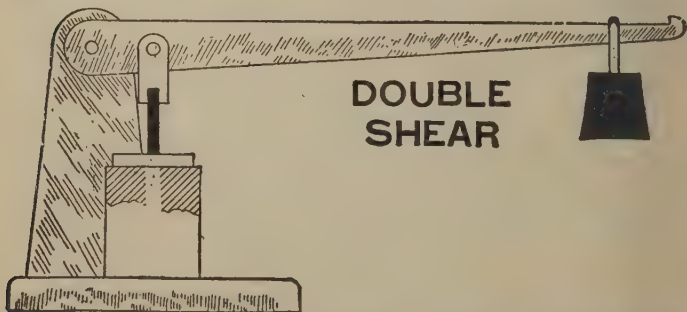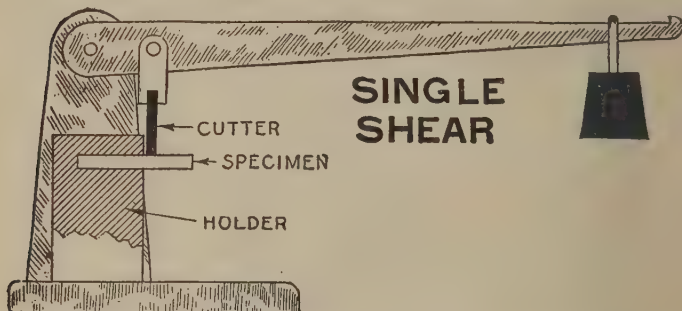
FIGS. 6,010 and 6,011.—*Single and double shear tests.* The specimen is placed in the holder and the stress applied. The cutter shears the metal in a single place for single shear and in two planes for double shear.

sections of a member to slip past each other. When so acted upon the member is said to be *in shear*.

Strain.—According to *Wood* it is a name given to the kind of alteration

produced by the *stresses*. The distinction between stress and strain is not always observed, there being much confusion among writers as to these terms.

Stress.—1. An internal action or *internal force* set up between the adjacent molecules of a body when acted upon by forces. 2. The force, or combination of forces, which produces a strain.

FIXED END

ELEMENT OF SURFACE BEFORE DEFLECTION
ELEMENT OF SURFACE AFTER DEFLECTION
SIZE OF SPECIMEN
USUALLY 1 INCH IN DIAM. BY 20 INCHES LONG

DEFLECTOR INDICATOR
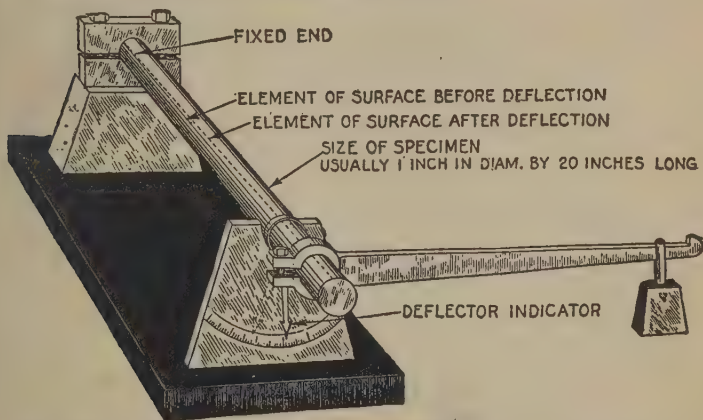
FIG. 6,012.—*Tortion test.* The specimen is gripped in the head so that it cannot turn and the deflector indicator attached; this end free to turn on the support. Tortion is applied by the weight, which twists the specimen in a clockwise direction, thus an element of its surface is distorted from a straight line, to a spiral form, the amount of distortion depending upon the intensity of the tortional force applied and the resisting power of the metal. By attaching a suitable scale, at the deflection end, the amount of twist can be read in degrees. The result sought in tortional tests are to determine the tortional elastic limit and ultimate tortional strength. Since the strain varies over the sectional area, it cannot be expressed as pounds per square inch, but must be stated as *inch pounds*. The value is obtained by multiplying the pull applied by the lever arm by the distance through which it acts. Thus if the weight be 100 pounds and the lever arm be 30 inches, then the tortional stress correspondingly is $100 \times 30 = 3,000$ inch-pounds. Again if the indicator register 20° on a 20-inch specimen the deflection in twist is stated as $20° \div 20$ inches $= 1°$ per inch.

Tensile strength.—The cohesive power by which a material resists an attempt to pull it apart in the direction of its fibers, this bears no relation to its capacity to resist compression.

Tension.—The stress or force by which a member is pulled; when thus pulled, the member is said to be *in tension*.

Ultimate strength.—The maximum unit stress developed at any time before rupture.

Yield point.—The point at which the stresses and the strains become equal, so that deformation or *permanent set* occurs. The point at which the stresses equal the elasticity of a test piece.
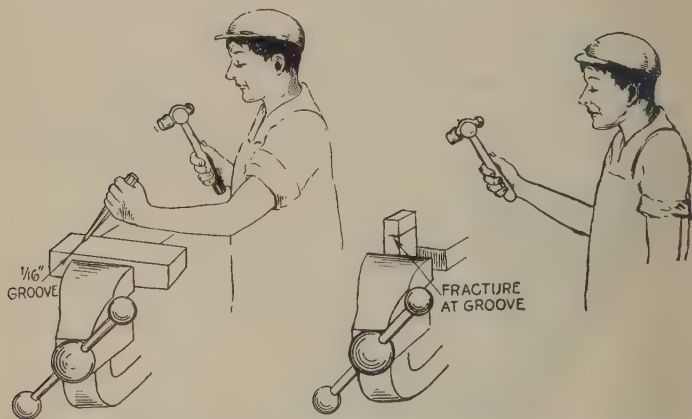
FIGS. 6,013 and 6,014.—*A. S. M. E. homogeneity test.* Made by grooving and fracturing specimen; described in detail in accompanying text.

CHAPTER 105

Sheet Metal

The term *sheet* is applied to material (with exception of lead) having a thickness less than No. 12 U. S. gauge. The U. S. government limits the thickness of sheets to No. 10 U. S. gauge. Ordinarily, sheet mills do not roll stock thinner than No. 30 gauge. As distinguished from *plate*, the term *sheet* signifies that the manufactured product is made entirely from the material specified.

For instance, *sheet lead* means lead in the form of a sheet, whereas *tin plate* (erroneously called *sheet tin*, and sometimes inexcusably just "*tin*") signifies a sheet of iron or steel coated with tin.

Sheet Metal Gauges.—The U. S. standard gauge for sheets and plate was legalized by Act of Congress, March 3, 1893, as a standard gauge to be used by the Custom House departments for sheet iron and steel. This gauge has since been adopted by about forty-five sheet and tin plate manufacturers. In addition to the U. S. standard gauge, the American or Brown & Sharpe gauge, the Birmingham gauge, and the standard decimal gauge are also used for iron and steel, as well as for copper and brass. A special gauge is used for tin plate, another for zinc, and still another for what is known as American "Russia iron." For the dimensions of these various gauges, see Wire and Sheet Metal Gauges, Tin Plate,

Sheet Metal and Wire Gauges

No.	United States Steel and Sheet Iron	British Imperial Standard	London	Washburn & Moen or United States Steel Wire	Birmingham or Stubbs	Brown & Sharpe or American Wire Gauge
0000000	.500	.500	....	....	....	......
000000	.46875	.464	....	....	....	......
00000	.4375	132	....	....	....	......
0000	.40625	.400	.454	.3938	.454	.460
000	.375	.372	.425	.3625	.425	.40964
00	.34375	.348	.380	.3310	.380	.36480
0	.3125	.324	.340	.3065	.340	.32495
1	.28125	.300	.300	.2830	.300	.28930
2	.265625	.276	.284	.2625	.284	.25763
3	.25	.252	.259	.2437	.259	.22942
4	.234375	.232	.238	.2253	.238	.20431
5	.21875	.212	.220	.2070	.220	18194
6	.203125	.192	.203	.1920	.203	.16202
7	.1875	.176	.180	.1770	.180	.14428
8	.171875	.160	.165	.1620	.165	.12849
9	.15625	.144	.148	.1483	.148	.11443
10	.140625	.128	.134	.1350	.134	.10189
11	.125	.116	.120	.1205	.120	.09074
12	.109375	.104	.109	.1055	.109	.08081
13	.09375	.092	.095	.0915	.095	.07196
14	.078125	.080	.083	.0800	.083	.06408
15	.0703125	.072	.072	.0720	.072	.05707
16	.0625	.064	.065	.0625	.065	.05082
17	.05625	.056	.058	.0540	.058	.04525
18	.05	.048	.049	.0475	.049	.04030
19	.04375	.040	.040	.0410	.042	.03589
20	.0375	.036	.035	.0348	.035	.03196
21	.034375	.032	.0315	.0317	.032	.02846
22	.03125	.028	.0295	.0286	.028	.025347
23	.0281	.024	.027	.0258	.025	.022571
24	.025	.022	.025	.0230	.022	.0201
25	.021875	.020	.023	.0204	.020	.0179
26	.01875	.018	.0201	.0181	.018	.01594
27	.0171875	.0164	.0187	.0173	.016	.014195
28	.015625	.0148	.0165	.0162	.014	.012641
29	.0140625	.0136	.0155	.0150	.013	.011257
30	.0125	.0124	.0137	.0140	.012	.010025
31	.0109375	.0116	.0122	.0132	.010	.008928
32	.01015625	.0108	.0112	.0128	.009	.00795
33	.009375	.0100	.0102	.0118	.008	.00708
34	.0085937	.0092	.0095	.0104	.007	.0063
35	.0078125	.0084	.009	.0095	.005	.00561
36	.0070312	.0076	.0075	.0090	.004	.005
37	.0066406	.068	.0065	.0085	....	.00445
38	.00625	.0060	.0057	.0080	....	.003965

Zinc and Russia iron gauge. The so called standard decimal gauge for sheet metal was adopted in 1895 by the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association. In this gauge the number for each thickness is the number of thousandths of an inch
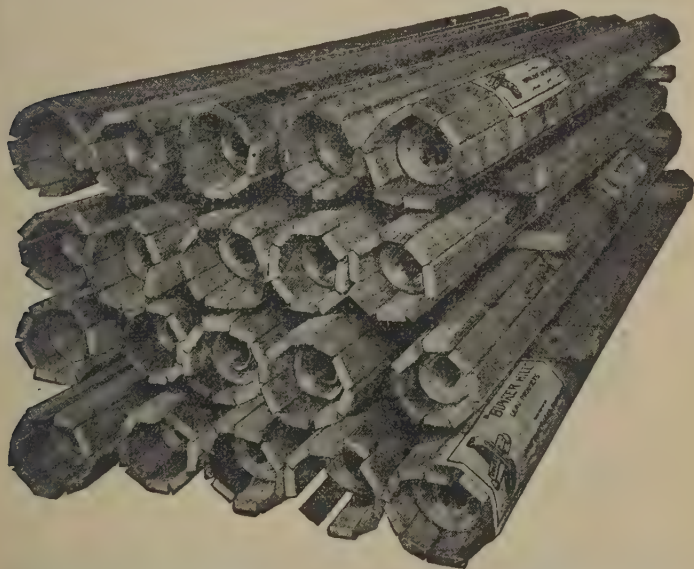
Fig. 6,015.—Sheet lead as packed ready for shipment showing approximately 16 tons of 12 lb. sheet lead.

of the thickness of the metal, so that a sheet .016 inch thick is No. 16 in the decimal gauge. A number of large manufacturing concerns have discontinued the use of gauge numbers entirely in referring to wire, sheet metal, etc., and give the dimension in decimals of an inch.

How Sheet Lead Is Manufactured.—Pure refined pig lead is first melted to the correct temperature and then poured into a moulding pan which has been preheated, the heat being maintained on the pan until all dross has been thoroughly skimmed from the lead. This slab of lead is allowed to cool slowly. Lead cooled rapidly has a tendency to crystallize, thereby making the finished product a very poor quality
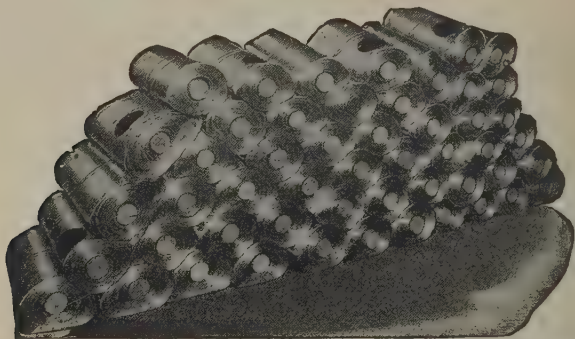
Fig. 6,016.—Bunker Hill brand 14 in. lead flashing ready for delivery. Weight 2½ lbs. per sq. ft. in rolls weighing about 100 lbs. per roll. The round wooden sticks on which the flashing is rolled are used for the purpose of protecting the edges against marring or doubling over and cracking. This happens very often where flashing is not protected in this manner.

sheet, allowing a far more rapid deterioration from chemical action. Dross in sheet lead causes a roughened surface and sometimes penetrates partly through the sheet in which case it is not visible on account of the glazed surface, but nevertheless leaves the sheet so that chemical action of acids would cause a rapid deterioration.

With the method used this is impossible, resulting in a perfect sheet lead product. When the lead cools it solidifies into a solid mass which in the terms of the lead worker is called a *slab*. It weighs about 3 tons and is

SHEET LEAD	SHEET TIN
1 lb. per sq. ft. ⅟₆₄ inch.	1 lb. per sq. ft. ⅟₄₀ inch.
1½ lbs. per sq. ft. ⅟₄₃ inch.	1½ lbs. per sq. ft. ⅟₂₇ inch.
2 lbs. per sq. ft. ⅟₃₂ inch.	2 lbs. per sq. ft. ⅟₂₀ inch.
2½ lbs. per sq. ft. ⅟₂₄ inch.	2½ lbs. per sq. ft. ⅟₁₆ inch.
3 lbs. per sq. ft. ³⁄₆₄ inch.	3 lbs. per sq. ft. ⅟₁₃ inch.
4 lbs. per sq. ft. ⅟₁₆ inch.	3½ lbs. per sq. ft. ⅟₁₁ inch.
5 lbs. per sq. ft. ⁵⁄₆₄ inch.	4 lbs. per sq. ft. ⅟₁₀ inch.
6 lbs. per sq. ft. ³⁄₃₂ inch.	4½ lbs. per sq. ft. ⅛ inch.
8 lbs. per sq. ft. ⅛ inch.	5 lbs. per sq. ft. ⅛ inch.
16 lbs. per sq. ft. ¼ inch.	10 lbs. per sq. ft. ¼ inch.
32 lbs. per sq. ft. ½ inch.	20 lbs. per sq. ft. ½ inch.

FIGS. 6,017 to 6,038.—Thickness and weight of sheet lead and sheet tin

approximately 4 ins. thick and 8 ft. 6 ins. in width. It is removed when completely cooled with large tongs and placed on the small rolls that automatically carry the slab up to the sheet rollers which do the work of rolling out the lead, reducing it to the required thickness. Ordinarily sheet lead is produced in the mill from 2½ lbs. per sq. ft. up to any desired weight.

The table on page **1,243** shows thicknesses and weights of sheet lead, and the maximum sizes in which sheet lead is ordinarily furnished are given in the following table:

Maximum Sizes of Sheet Lead

Weight per square foot		Size	Weight per square foot		Size
1	lb.	8' x 20'	10	lb.	11'6" x 40'
1½	"	8' x 20'	12	"	11' x 40' or 11'6" x 35'
2	"	7' x 45'	14	"	11'6" x 40' or 11'9" x 30'
2½	"	9' x 45'	16	"	11'6" x 40' or 11'9" x 30'
3	"	10' x 45'	20	"	11'6" x 40' or 11'9" x 38'
3½	"	10' x 45'	20	"	11'9" x 36'
4	"	10' x 45'	24	"	11'9" x 30'
5	"	10' x 43'	24	"	11' x 34' or 11'6" x 32'
6	"	10' x 43' or 11' x 40'	30	"	11' x 27' or 11'6" x 25'6"
6	"	11'6" x 30' or 11'9" x 25'	30	"	11'6" x 24'6" or 12' x 16'
8	"	10' x 40' or 11'6" x 35'	40	"	11' x 24' or 12' x 16'
10	"	11'6" x 30' or 11' x 40' or 10' x 48'	60	"	12' x 12'

Sheet Tin.—The practice of confusing *sheet tin* with *tin plate* (ignorantly called just *"tin"*) should be avoided by the well informed plumber. At ordinary temperatures tin can be beaten and rolled into thin leaves known as sheet tin. It comes in weights of from 1 lb. to 20 lbs. per sq. ft. The accompanying diagrams, figs. 6,017 to 6,038, show comparative thicknesses and weights of sheet lead and sheet tin.

Tin Plate.—By definition, *tin plate consists of sheets of iron*
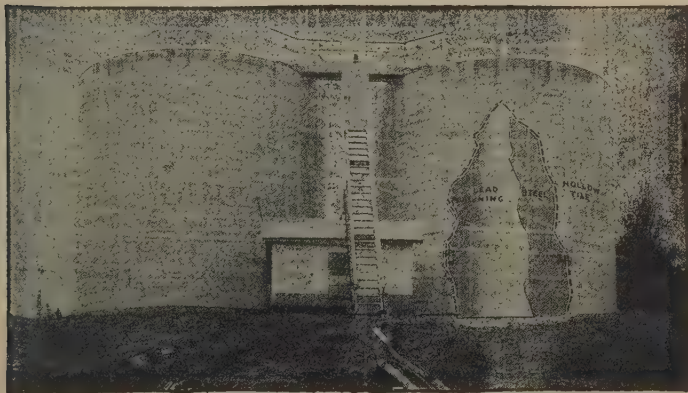
Fig. 6,039.—Lead lined sulphuric acid tanks. Sectional view at right shows method of construction; outer wall of hollow tile, reinforcement riveted steel and inner lining, walls, and bottom sheet lead.

or steel coated with tin for protection against corrosion, as distinguished from sheet tin which consists of sheets entirely of tin. Tin plate is produced from steel sheets which range in thickness usually from 16 to 38 Stubbs wire gauge. After the sheets are rolled, they are pickled to remove the scale, washed with water to remove the acid, and then annealed, pickled, washed,

and passed through molten tin by means of from four to six pairs of rolls immersed in the molten tin.

Formerly when iron was used instead of steel, the highest quality tin plate was called *charcoal plate* and the second quality, *coke plate*, these names signifying the mode of manufacture of the iron used. Although steel is now used, these names have been retained, but refer to the quality of the tin coating and finish.
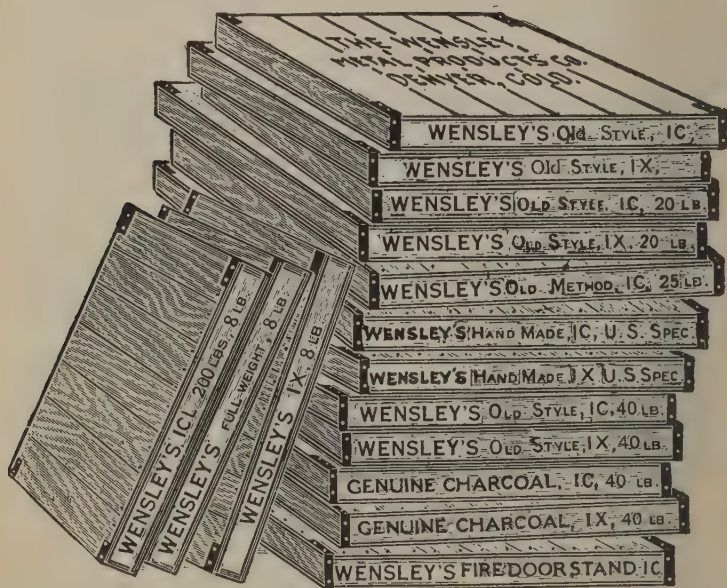
Fig. 6,040.—Wensley's Terne or roofing plates as packed for shipment showing marking on boxes for various grades.

At present, charcoal plates have the heavier coating and higher finish while coke plates have a light coating. The amount of coating of pure tin when made according to the specifications of one manufacturer is .023 lb. per sq. ft.

The various grades of charcoal plates are designated by the letters A to AAAAA, the latter having the heaviest coating and highest polish, thus: AAAAA tin plate is especially adapted for nickel plating.

Tin plates are ordinarily made in sizes of 10×14 ins. and multiples of that size. The sizes generally used are 14×20 and 20×28 ins. Tin plates are packed in unit boxes called "base boxes," each holding 112 14×20 in. plates or 31,360 sq. ins. of any size.

Plates lighter than 65 lbs. per base box (No. 36 gauge) are known as taggers tin. The stock size of coke tin plates is 20×28 ins. and the basis on which all coke plates are sold and figured is the base box of 112, 14×20 plates,

FIGS. 6,041 and 6,042.—Appearance of terne plates. Fig. 6,041, old style 1 C; fig. 6,042, dry finish.

Terne or "Roofing" Plates.—In distinction from plates coated only with tin, terne plates are made of soft steel or wrought iron and covered with a mixture of lead and tin. There are two methods employed in coating: 1, the old or original method in which the block plates are dipped by hand into a mixture of tin and lead and allowed to take all the coating possible; 2, the later method, known as the patent

roller process by which the plates are put into a bath of tin and lead and then passed between rolls.*

Sheet Metal.—Iron and steel may be obtained rolled into thin sheets of various sizes. Sheet steel is made from soft

FIG. 6,043.—Wensley open hearth blue annealed sheet steel (common black sheets).

FIG. 6,044.—Wensley open hearth galvanized (sheet steel). Made of extra soft, ductible steel coated with prime spelter.

steel containing a low percentage of carbon rolled to thicknesses ranging from No. 10 (.141 in.) to No. 30 (.013 in.) U. S. standard gauge.

The sizes of sheets generally carried in stock are 24, 26, 28 and 30 ins. width by 72, 84, 96 and 120 ins. length. Nos. 10 to 16 inclusive are also made in widths 36, 40, 42 and 48 ins. by 144 ins. length; Nos. 17 to 24 also made 36×144 ins.

*NOTE.—The pressure of these rolls leaves on the iron or steel a thickness of coating which, to a great extent, determines the value of the plates. The rolls are adjustable to give any desired thickness of coating. Most plates are made by this process. Some makers employ a variation of this patent process by which the plates are given an extra dip by hand in an open pot, to give a *hand dipped finish*. It is claimed the hand dipped plates will last longer than those not hand dipped. The best roofing plates always have the hand stamped on them and this should be considered in purchasing plates.

Galvanized Sheet Metal.—The term *galvanized* is defined as *to heat with a continuous electric current.* The term is improperly but almost universally applied to iron or steel coated with zinc by immersion in a molten bath of that metal, without galvanization. Galvanized sheet metal protects it against corrosion, the zinc becoming covered with a film of zinc carbonate which protects the metal from further chemical action. If the galvanizing be poorly done and the coating does not adhere properly, and if any acid from the pickle or any chloride

Fig. 6,04⁵ —Wensley cross crimped galvanized sheets. ⅛ in. crimps. Easily worked in a cornice brake. Extensively used for cornice work. Regular sizes any length up to 120 ins. and any width up to 36 ins.

from the flux remain on the iron, corrosion takes place under the zinc coating. The zinc used for galvanizing should contain at least 98% pure zinc.

Figs. 6,043 and 6,044 show sheet steel as tied together with bands for shipment. Galvanized sheets may be obtained cross crimped as in fig. 6,045, or corrugated as in fig. 6,046.

Fig. 6,047 shows method of securing corrugated sheet roof with nails and lead washers. Lead washers used as indicated make a watertight joint on any surface, whether concave, convex or flat. They prevent both the nail head cutting into the sheet and rust formation underneath. The first rust on a metal roof usually appears around the nail holes. Water collects in the small offsets made by the nail heads, the two metals (nails and sheets) undergo oxidizing or rusting process, and

this action in time loosens the nail head and allows moisture to enter. The use of lead washers practically eliminates the trouble, as they do not rust.

Sheet Brass.—This is a composition of copper and zinc in varying proportions according to the purpose for which it is intended. Here such alloys as may be rolled and drawn are considered, and in a general way this may be said to include
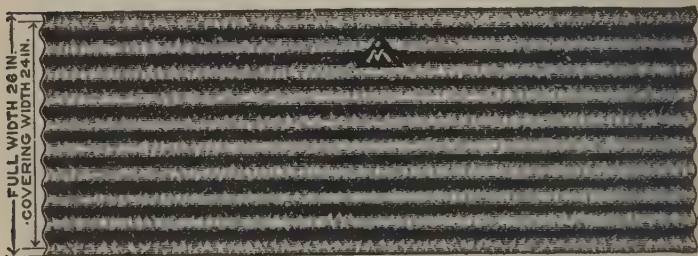
FIG. 6,046.—Wensley 2½ in. corrugated open hearth steel sheets; painted or galvanized.
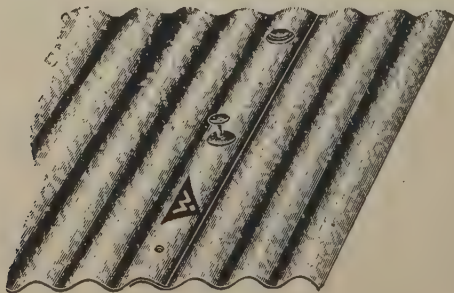
FIG. 6,047.—Wensley corrugated sheets as attached to roof with nails and washers. About 225 washers to the pound and require about ⅛ lb. to lay a square.

only alloys containing not less than 60% of copper. The malleability and ductility depend upon the amount of copper in the mixture. The ordinary yellow brass of commerce, known to the trade as high brass (meaning high in zinc) will vary from 60% copper and 40% zinc up to 75% copper and 25% zinc, according to the physical characteristics the metal must possess to be adapted to the purpose in view. To insure the best results this purpose should be known to the manufacturer, as his experience will enable him to determine what particular mixture and temper is necessary. The important brasses are the following: *Drawing brass*, for making articles drawn to shapes with punches and dies in drawing presses; *spinning brass*, for making articles which are spun to shape on chucks; *leaded brass* or *clock brass*, which contains a small percentage of lead in the mixture and is free cutting and drilling, but not suitable for drawing or spinning; *stamping brass*, suitable for making articles cut to shape and left flat, or bent to shape, but not drawn or spun; *brazing brass*, made of a mixture which will not fuse at the high heat necessary for hard solder brazing. It is also an excellent drawing brass. Low brass is an alloy of copper and zinc, meaning low in zinc contents, and the name is not generally applied to any mixture containing less than 80% copper. It is darker in color than high brass, is very tough and ductile; may be spun and drawn to almost any desired shape.

Commercial or architectural bronze is the name applied by American manufacturer to a mixture of 90 parts of copper and 10 parts zinc. When polished it has a rich gold color and is much used where ornamentation must be combined with durability. It is extensively used for interior work, such as fireproofing window sash and doors, grille work, elevator enclosures, signs and tablets. Among European manufacturers this metal is known as "Tombac."

Gilding metal is an alloy containing more copper than architectural bronze and varies from 12 parts of copper and 1 part of zinc to 18 parts of copper and 1 part of zinc. It closely resembles copper in appearance but is tougher and stronger; it is very ductile and may be drawn and spun or brazed; it is not extensively used and is generally made to meet some special requirement.

Bronze.—There is much confusion in the metal trades as to what is meant by "Bronze". In the early days of the art the name was only applied to mixtures of copper and tin, and it is to be regretted that the practice was ever abandoned. The name originally designated a non-corrosive metal dark in color, hard in temper, and of high tensile strength, but later day practice has sanctioned the use of the name for any metal that possesses any of these characteristics according to the whim of the manufacturer and regardless of the composition.

Temper.—Any of the sheet alloys may be obtained in the proper temper for the work if care be taken to indicate what is required. Spinning brass is annealed soft. Drawing brass is given a special drawing anneal and the various degrees of hardness in hard brass depends upon how much the metal is reduced in thickness, after the final annealing, measured by gauge numbers. Quarter hard (one number) is stiffer than soft brass, but can be double seamed without cracking; half hard (two numbers) is a temper suitable for punching, blanking and bending. Will double seam in lighter gauges. Regular hard (four numbers) is too stiff to work beyond a right angle bend across the grain of the metal. Spring (6 to 8 numbers) hard and sufficiently elastic to return to original position after deflection.

Sheet Copper.—Rolling copper to an exact thickness is not practicable. By custom, a variation of not over $\frac{1}{2}$ oz. either over or under specified weight is permissible on order for sheets, bottoms and circles 16 ozs. and lighter.

The thickness should be indicated either in terms of weight per sq. ft. or in decimal of an inch, or by gauge; if by gauge, care being taken to state whether Stubbs or B. & S. gauge.

Further, the finish should be stated, whether hot rolled, cold rolled and annealed, cold rolled, or cold rolled and polished; if tinned, whether on one side or both sides; if polished, whether on one side or both sides.

Sheet copper may be also obtained crimped, or corrugated tinned on one side.

German Silver.—This is an alloy of nickel, copper and zinc, the quality being designated by figures indicating the percentage of nickel in the mixture. It is a white metal when containing 18 per cent. or more of nickel shading off toward the yellow color of brass as the percentage of nickel is reduced. While not so soft and ductile as brass, it may be worked with tools and spun in the same manner, and in practically the same variety of shapes. The metal has a very fine, dense grain, takes a high polish, is non-corrosive under atmospheric influences, and is extensively used for ornamental purposes. It is superior to nickel plated brass because, being a white metal throughout, there is no plating to wear off. It is frequently used in sheet form for lining work boards and sinks in pantries, cafes and soda fountains. When drawn into tubes

it is available for use as basin supply pipes and other service pipes in lavatories. German silver is not a good conductor of electricity and German silver wire is used to a very large extent as a resistance wire in electrical instruments.

CHAPTER 106

Pipe

Pipe.—There are numerous kinds of pipe manufactured to meet the varied conditions of service, and they may be classed:

1. According to the material used, as:

   a. Wrought iron
   b. Wrought steel.
   c. Cast iron.
   d. Copper.
   e. Brass.
   f. Lead.

2. According to the process of manufacture, as:

   a. Brazed.
   b. Butt welded.
   c. Lap welded.
   d. Riveted.

3. According to the kind of joint used, as:

   a. Threaded.
   b. Flanged.
   c. Spigot.

4. According to strength:

   a. Standard.
   b. Heavy.
   . Extra heavy.

Wrought Iron or Steel Welded Pipe.—For conveying steam, gas, air, and water under pressure, wrought iron and steel pipes

FIG. 6,048.—*Lap weld process.* The skelp used in making lap welded tubes is rolled to the necessary width and gauge for the size tubes to be made, the edges being scarfed and overlapped when the skelp is bent into shape, thus giving a comparatively large welding surface, compared with the thickness of the plate. The skelp is first heated to redness in a "bending furnace," and then drawn from the front of the furnace through a die, the inside of which gradually assumes a circular shape, so that the skelp when drawn through is bent into the form of a tube with the edges overlapping as shown. The skelp so formed is heated evenly to the welding temperature in a regenerative furnace. When the proper temperature is obtained, the skelp is pushed through an opening in the front of this furnace into the welding rolls, passing between two rolls set one above the other, each having a semi-circular groove, so that the two together form a circular pass. Between these rolls a mandrel is held in position inside the tube, the lapped edges of the skelp being firmly pressed together at a welding heat between the mandrel and the rolls. The tube then enters a similarly shaped pass to correct any irregularities and to give the outside diameter required. It will be noted that the outside diameter is fixed by these rolls; any variation through gauge, therefore, makes a proportional variation in the internal diameter. This also applies to butt weld pipe. Finally, the tube is passed to the straightening, or cross rolls, consisting of two rolls set with their axes askew. The surfaces of these rolls are so curved that the tube is in contact with each for nearly the whole length of the roll, and is passed forward and rapidly rotated when the rolls are revolved. The tube is made practically straight by the cross rolls, and is also given a clean finish with a thin, firmly adhering scale. After this last operation, the tube is rolled up an inclined cooling table, so that the metal will cool off slowly and uniformly without internal strain. When cool enough, the rough ends are removed by cold saws or in a cutting off machine, after which the tube is ready for inspection and testing. In the case of some sizes of double extra strong pipe (3 inch to 8 inch), made by the lap weld process, the pipes are first made to such sizes as will telescope one within the other, the respective welds being placed opposite each other; these are then returned to the furnace, brought to the proper heat, and given a pass through the welding rolls. While a pipe made in this way is, in respect to its resistance to internal pressure, as strong or stronger than when made from one piece of skelp, it is not necessarily welded at all points between the two tubular surfaces; however, each piece is first thoroughly welded at the seam before telescoping.

are largely used. There is a difference of opinion as to the superiority of the one material over the other, especially in the matter of corrosion.

Some think that the cinder which remains in the wrought iron breaks up the continuity of the metal and tends to retard corrosion, while others

BUTT

Fig. 6,049.—*Butt weld process.* Skelp used in making butt welded pipe comes from the rolling department of the steel mills with a specified length, width and gauge, according to the size pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely, as shown. The skelp for all butt welded pipe is heated uniformly to the welding temperature, in furnaces similar in general construction to those used in lap welding. The strips of steel when properly heated are seized by their ends with tongs and drawn from the furnaces through bell shaped dies, or rings. The inside of these dies is so shaped that the plate is gradually turned around into the shape of a tube, the edges being forced squarely together and welded. For some sizes, the pipes are drawn through two rings consecutively at one heat, one ring being just behind the other, the second one being of smaller diameter than the first. The pipes are then run through sizing and cross rolls similar to those used in the lap weld process, obtaining thereby the correct outside diameter and finish. The pull required to draw double extra strong (hydraulic) pipe by this process is so great, on account of the thickness of the skelp, that it is found necessary to weld a strong bar on the end of the skelp, thereby distributing the strain. With this bar the skelp is drawn through several dies of decreasing size, and is reheated between each draw until the seam is thoroughly welded. It is evident that the skelp is put to a severe test in this operation, and, unless the metal be sound and homogeneous, the ends will most always be pulled off.

believe there is little or no difference in the rust resisting qualities of the two materials. However, judging from the amount of printed matter that has been circulated by manufacturers of steel pipe, they are having some

difficulty trying to convince every one that steel pipe will resist corrosion as long as iron pipe.

Wrought iron pipe, because of the higher cost of manufacture, has been largely displaced by steel.

The term "wrought iron pipe" is often *erroneously* used to refer to pipes made to Briggs' standard sizes rather than of the material, hence, in ordering pipe, if iron pipe be wanted
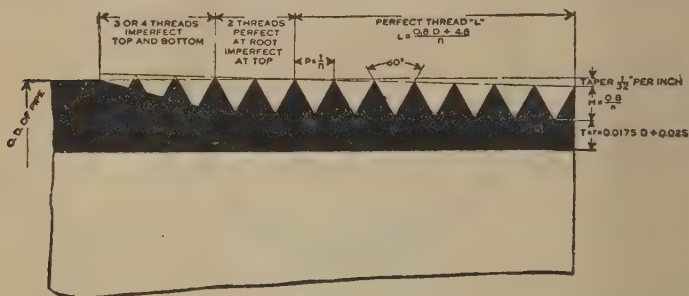
Fig. 6,050.—Briggs standard pipe thread. This standard is due to Robert Briggs, C.E., who prepared a paper on "American Practice in Warming Buildings by Steam," for the Institution of Civil Engineers of Great Britain (vol. lxxi, Session 1882-83, Part 1). This paper was presented and read after his death. The following extracts from the paper (see also A.S.M.E. *transactions*, vol. viii), give data upon which the Briggs standard is based: "The taper employed for the conical tube ends is uniform with all makers of tubes or fittings, namely an inclination of 1 in 32 to the axis. Custom has established also a particular length of screwed end for each different diameter of tube. Tubes of the several diameters are kept in stock by manufacturers and merchants, and form the basis of a regular trade in the apparatus for warming by steam. A knowledge of all these particulars is therefore essential for designing apparatus for the purpose. The ruling dimension in wrought iron tube work is the external diameter of certain nominal sizes, which are designated roughly according to their internal diameter. These nominal sizes were mainly established in the English tube trade between 1820 and 1840, and certain pitches of screw thread were then adopted for them, the coarseness of the pitch varying roughly with the diameter, but in an arbitrary way utterly devoid of regularity. The length of the screwed portion on the tube end varies with the external diameter of the tube according to an arbitrary rule of thumb; whence results, for each size of tube a certain minimum thickness of metal at the outer extremity of the tapering screwed tube end. It is the determination of this minimum thickness of metal for the tapering screwed end of a wrought iron tube, which constitutes the question of mechanical interest. The figure shows a longitudinal section of the tapering tube end, with the screw thread as actually formed *full size* for a nominal 2½-inch pipe, that is a pipe about 2½ inches internal diameter and 2⅞ inches actual external diameter.

instead of steel, care should be taken to specify *genuine wrought iron*, or *guaranteed wrought iron* pipe.

It is customary for manufacturers to stamp each length of such pipe as *genuine wrought iron* to distinguish it from steel,

AMERICAN BRIGGS STANDARD FOR TAPER AND STRAIGHT PIPE THREADS AND LOCK-NUT THREADS

ADOPTED BY THE COMMITTEE OF MANUFACTURERS ON STANDARDIZATION OF FITTINGS AND VALVES AND THE AMERICAN SOCIETY OF AMERICAN ENGINEERS
SEPTEMBER 17, 1913

A equals G—(0.05G+1.9)×$\frac{1}{N}$+$\frac{0.8}{N}$

B equals A+(8×.0625)

C equals B+$\left(\frac{4}{N}×.0625\right)$

D equals B+$\left(\frac{5}{N}×.0625\right)$

E equals (0.8G+4.8)×$\frac{1}{N}$+$\frac{2}{N}$

F equals American Briggs Standard.
N equals Number of threads per inch.
Total Taper ¾ inch per foot.
Depth of Thread $\frac{0.8}{N}$
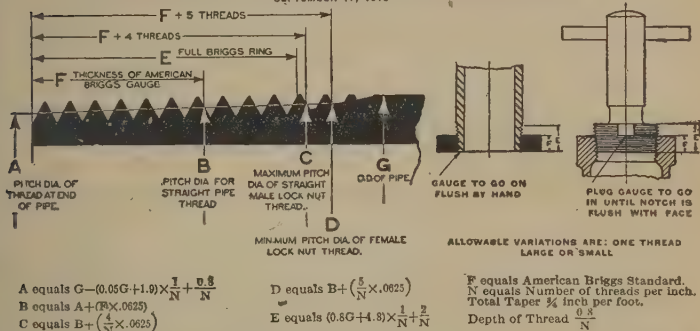
Figs. 6,051 to 6,053. —American Briggs standard pipe thread, and ring and plug gauges. The thread proportions are given in the formulae and table below.

AMERICAN BRIGGS STANDARD PIPE THREADS

Size	A	B	C	D	E	F	G	Depth of Thread	Threads per Inch
⅛	.36350	.37475	.38400	.38632	.2638	.150	.405	.02962	27
¼	.47739	.48989	.50378	.50725	.4018	.200	.540	.04444	18
⅜	.61201	.62701	.64090	.64437	.4078	.240	.675	.04444	18
½	.75843	.77843	.79628	.80075	.5337	.320	.840	.05714	14
¾	.96768	.98856	1.00671	1.01118	.5457	.339	1.050	.05714	14
1	1.21363	1.23863	1.26036	1.26580	.6828	.409	1.315	.06956	11½
1¼	1.55713	1.58338	1.60511	1.61055	.7068	.420	1.660	.06956	11½
1½	1.79609	1.82234	1.84407	1.84951	.7235	.420	1.900	.06956	11½
2	2.26902	2.29627	2.31801	2.32344	.7565	.438	2.375	.06956	11½
2½	2.71954	2.76216	2.79341	2.80122	1.1375	.682	2.875	.100	8
3	3.34063	3.38550	3.41975	3.42756	1.2000	.766	3.500	.100	8
3½	3.83750	3.88881	3.92006	3.92787	1.2500	.821	4.000	.100	8
4	4.33438	4.38713	4.41938	4.42619	1.3000	.844	4.500	.100	8
4½	4.83125	4.88593	4.91718	4.92499	1.3500	.875	5.000	.100	8
5	5.39074	5.44920	5.48055	5.48636	1.4063	.937	5.563	.100	8
6	6.44610	6.50597	6.53722	6.54503	1.5125	.958	6.625	.100	8
7	7.43985	7.50235	7.53360	7.54141	1.6125	1.000	7.625	.100	8
8	8.43360	8.50003	8.53128	8.53909	1.7125	1.063	8.625	.100	8
9	9.42735	9.49797	9.52922	9.53703	1.8125	1.130	9.625	.100	8
10	10.54532	10.62094	10.65219	10.66000	1.9250	1.21·	10.750	.100	8
11	11.53907	11.61938	11.65063	11.65844	2.0250	1.285	11.750	.100	8
12	12.53232	12.61782	12.64907	12.65688	2.0750	1.360	12.750	.100	8
14 O. D.	13.7750	13.87262	13.90387	13.91168	2.250	1.562	14 00	.100	8
15 O. D.	14.76875	14.87418	14.90643	14.91324	2.350	1.687	15.00	.100	8
16 O. D.	15.76250	15.87575	15.90700	15.91481	2.450	1.812	16.00	.100	8
17 O. D.	16.75625	16.87500	16.90625	16.91406	2.550	1.900	17.00	.100	8
18 O. D.	17.7500	17.87500	17.90625	17.91406	2.650	2.000	18.00	.100	8
20 O. D.	19.73750	19.87031	19.90156	19.90937	2.850	2.125	20.00	.100	8
22 O. D.	21.72500	21.86562	21.89687	21.90468	3.050	2.250	22 00	.100	8
24 O. D.	23.71250	23.86093	23.89218	23.89999	3 250	2.375	24 00	.100	8

and *no wrought iron pipe should be accepted* as such without the stamp.

Briggs' Standard.—Both wrought iron and steel pipes are made to the same standard of sizes. The nominal sizes of pipe 10 inches and under, and the pitches of the threads, were for the most part established in the British tube (called "pipe" in America) trade between 1820 and 1840. The sizes are designated roughly, according to their internal diameters.

Robert Briggs, about 1862, while superintendent of the Pascal Iron Works, formulated the nominal dimensions of pipe up to and including 10 inches. These dimensions have been broadly spread and are widely known as "Briggs' standard," as given in the following table.

Diameter of Standard Wrought Pipe

(Briggs' Standard)

Nominal internal diameter	Actual internal diameter d, in terms of actual external diameter D	Number of screw threads per inch	Depth of thread according to National Tube Co.
Inches	Inches		Inch
$\frac{1}{8}$	$d = .9631D — .1204$	27	.0296
$\frac{1}{4}$ and $\frac{3}{8}$	$d = .9622D — .1556$	18	.044
$\frac{1}{2}$ and $\frac{3}{4}$	$d = .9614D — .1857$	14	.0571
$1,1\frac{1}{4},1\frac{1}{2}$ and 2	$d = .9607D — .2152$	$11\frac{1}{2}$	.0696
$2\frac{1}{2}$ to 10	$d = .9587D — .2875$	8	.1

Quoting from Briggs:

"The number of screw threads per inch for the several sizes of tubes is here accepted from customary usage. It is the workman's approximation to the pitch practically desirable, and much reluctance must consequently be felt in calling it in question. Still it would have been better to investigate

NOTE. –The National Tube Co. state that "the wisdom of their decision to make steel pipe only is shown by the fact that between 80 and 90 per cent. of the pipe used to-day in the United States is steel pipe. In addition to the advantage of better service by using steel pipe it is possible to save from twenty to thirty per cent. on the first cost, due to the fact that pipe steel is made by machine rather than by hand process."

Figs. 6,054 to 6,056.—The three weights of wrought pipe. Fig. 6,054, *standard*; fig. 6,055, *extra strong*; fig. 6,056, *double extra strong*. Sometimes the word "heavy" is used in place of strong. The figures are actual size, showing proportions of the three grades of 1-inch wrought pipe.

the general case upon the basis of a pitch ranging in closer accordance with the range of tube diameter. Thus the nominal ½ inch tubes might have had 16 thread per inch; ¾ inch, 14 threads; 1 and 1¼ inch, 12 threads; 1½ and 2 inches, 11 threads; 2½ to 3½ inches, 10 threads; 4 to 6 inches, 8 threads; 7 to 9 inches, 7 threads; and 10 inches, not more than 6 threads per inch. The existing numbers of threads, however (as here given), are now too well established to be disturbed; at all events they must be taken in any statement of present practice."

By trade usage, the above rules have been extended to take in sizes up to 15 inches inclusive, except that the standard thickness is .375 in. Pipes larger than 15 inches nominal size are known by their outside diameter. The dimensions have also been extended to *extra strong* and *double extra strong* pipe, by retaining the outside diameter and allowing the inside diameter to decrease according to increase in thickness.

Weight of Pipe.—In order to adapt wrought pipe

to different pressures it is regularly made up in three grades of thicknesses (weights) known as

1. Standard.
2. Extra strong (or heavy).
3. Double extra strong (or heavy).

For the three grades, the outside diameters of the listed sizes remain the same, but the thickness is increased *by decreasing the inside diameter*.

SIZE	STANDARD	EXTRA STRONG	DOUBLE EXTRA STRONG
½	◯	◯	◉
¾	◯	◯	◉
1	◯	◯	◉

Figs. 6,057 to 6,065.—Three sizes of standard, extra strong, and double extra strong welded pipe showing relative thickness; about half size.

For instance, figs. 6,057 to 6,059 show sections of the above three grades of pipe of the same listed size.

A grade of pipe known as *merchant pipe* is short weight pipe.

It is necessary to guard against this short weight pipe which formerly was extensively made to meet the demand of sharp jobbers, but now reputable companies have given up the manufacture of such pipe.

Merchant pipe is usually 5 to 10 per cent thinner than full weight pipe. It should be carefully avoided in work of any importance, as the extra cost of maintenance will soon overbalance the small difference in first cost. As a precaution against merchant pipe, orders should specify full weight pipe.

Manufacture and Tests.—Welded steel pipe should be made from uniformly good quality soft, weldable steel, rolled from solid ingots. Sufficient crop should be cut from the ends to insure sound material, and the steel shall be given the most approved treatment in heating and rolling.

The steel from which the pipe is made must, according to the National Tube Co., show the following physical properties:

Tensile strength, 50,000 pounds   Elongation in 8 ins., 18 per cent
Elastic limit over 30,000 pounds   Reduction in area, 50 per cent

The test pressures given in the table on page following are applied to the respective sizes of butt and lap welded pipe for the three grades or weights:

Bursting and Safe Working Pressures.—Numerous factory tests to determine the actual bursting pressure of wrought pipe have proved Barlow's formula to be correct. Barlow's formula

$$BP = \frac{2T \times TS}{OD}$$

in which BP = bursting pressure in lbs. per sq. in.; T = thickness of the wall in ins.; OD = outside diameter of pipe in ins.; TS = tensile strength.

The value of TS as determined from actual tests by the Crane Co. is 40,000 lbs. per sq. in. for butt welded pipe and 50,000 lbs. for lap welded steel pipe. The table on following page is based on Barlow's formula and the working pressures given is based on a factor of safety of eight.

Test Pressures

National Tube Co.

STANDARD			EXTRA STRONG			DOUBLE EXTRA STRONG		
Size	Test pressure in pounds		Size	Test pressure in pounds		Size	Test pressure in pounds	
	Butt	Lap		Butt	Lap		Butt	Lap
⅛	700		⅛	700				
¼	700		¼	700				
⅜	700		⅜	700				
½	700		½	700		½	700	
¾	700		¾	700		¾	700	
1	700		1	700		1	700	
1¼	700	1,000	1¼	1,500		1¼	2,200	3,000
1½	700	1,000	1½	1,500	2,500	1½	2,200	3,000
2	700	1,000	2	1,500	2,500	2	2,200	3,000
2½	800	1,000	2½	1,500	2,000	2½	2,200	3,000
3	800	1,000	3	1,500	2,000	3		3,000
3½		1,000	3½		2,000	3½		2,500
4		1,000	4		2,000	4		2,500
4½		1,000	4½		1,800	4½		2,000
5		1,000	5		1,800	5		2,000
6		1,000	6		1,800	6		2,000
7		1,000	7		1,500	7		2,000
8		800	8		1,500	8		2,000
8		1,000				8		
9		900	9		1,500	9		
10		600	10		1,200	10		
10		800				10		
10		900				10		
11		800	11		1,100	11		
12		600	12		1,100	12		
12		800				12		
13		700	13		1,000	13		
14		700	14		1,000	14		
15		600	15		1,000	15		

Properties of Standard Wrought Pipe

	Diameters		Nominal Thickness	Circumference		Transverse Areas			Length of Pipe per Square Foot of		Length of Pipe Containing One Cubic Foot	Nominal Weight per Foot		Number of Threads Per Inch of Screw
Size	External	Approximate Internal		External	Internal	External	Internal	Metal	External Surface	Internal Surface		Plain Ends	Threaded and Coupled	
Inches	Inches	Inches	Inches	Inches	Inches	Sq. Ins.	Sq. Ins.	Sq. Ins.	Feet	Feet	Feet	Feet	Feet	
⅛	.405	.269	.068	1.272	.845	.129	.057	.072	9.431	14.199	2533.775	.244	.245	27
¼	.540	.364	.088	1.696	1.144	.229	.104	.125	7.073	10.493	1383.789	.424	.425	18
⅜	.675	.493	.091	2.121	1.549	.358	.191	.167	5.658	7.747	754.360	.567	.568	18
½	.840	.622	.109	2.639	1.954	.554	.304	.250	4.547	6.141	473.906	.850	.852	14
¾	1.050	.824	.113	3.299	2.589	.886	.533	.333	3.637	4.635	270.034	1.130	1.134	14
1	1.315	1.049	.133	4.131	3.296	1.358	.864	.494	2.904	3.641	166.618	1.678	1.684	11½
1¼	1.660	1.380	.140	5.215	4.335	2.164	1.495	.669	2.301	2.767	96.275	2.272	2.281	11½
1½	1.900	1.610	.145	5.969	5.058	2.835	2.036	.799	2.010	2.372	70.733	2.717	2.731	11½
2	2.375	2.067	.154	7.461	6.494	4.430	3.355	1.075	1.608	1.847	42.913	3.652	3.678	11½
2½	2.875	2.469	.208	9.032	7.757	6.492	4.788	1.704	1.328	1.547	30.077	5.793	5.819	8
3	3.500	3.068	.216	10.996	9.638	9.621	7.393	2.228	1.091	1.245	19.479	7.575	7.616	8
3½	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	.954	1.076	14.565	9.109	9.202	8
4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	.848	.948	11.312	10.790	10.889	8
4½	5.000	4.506	.247	15.708	14.156	19.635	15.947	3.688	.763	.847	9.030	12.538	12.642	8
5	5.563	5.047	.258	17.472	15.856	24.306	20.006	4.300	.686	.756	7.198	14.617	14.810	8
6	6.625	6.065	.280	20.813	19.054	34.472	28.891	5.581	.576	.629	4.984	18.974	19.185	8
7	7.625	7.023	.301	23.955	22.063	45.664	38.738	6.926	.500	.543	3.717	23.544	23.769	8
8	8.625	8.071	.277	27.096	25.256	58.426	51.164	7.265	.442	.473	2.815	24.696	25.000	8
8	8.625	7.981	.322	27.096	25.073	58.426	50.027	8.399	.442	.478	2.878	28.554	28.809	8
9	9.625	8.941	.342	30.228	28.089	72.760	62.786	9.974	.396	.427	2.294	33.907	34.188	8
10	10.750	10.192	.279	33.772	32.019	90.763	81.585	9.178	.355	.374	1.765	31.201	32.000	8
10	10.750	10.136	.307	33.772	31.843	90.763	80.691	10.072	.355	.376	1.785	34.240	35.000	8
10	10.750	10.020	.365	33.772	31.479	90.763	78.855	11.908	.355	.381	1.826	40.483	41.132	8
11	11.750	11.000	.375	36.914	34.558	108.431	95.033	13.401	.325	.347	1.515	45.557	46.247	8
12	12.750	12.090	.330	40.055	37.982	127.676	114.800	12.876	.299	.315	1.254	43.773	45.000	8
13	12.750	12.000	.375	40.055	37.699	127.676	113.097	14.579	.299	.318	1.273	49.562	50.706	8

Cast Iron Pipe.—These are usually made with *spigot* and *bell* joints, one end of each pipe being chamfered out to form a *socket*, *bell* or *hub*, which receives the other extremity of the next length.

The head or spigot end is sometimes turned to fit accurately in the bored-out bell, but it is usually cast to form with a raised bead around the end, which fits snugly into the socket, thus forming an annulus for the reception of the jointing material.

Cast Iron Flanged Pipe

Table of Standard Dimensions

Nominal Diameter Millimeters	Nominal Diameter Inches	Diameter of Flange Inches	Diameter of Bolt Circle, Inches	Number of Bolts	Diameter of Bolts Inches	CLASS A 100 FOOT HEAD 43 POUNDS PRESSURE Th'k-ness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS B 200 FOOT HEAD 86 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS C 300 FOOT HEAD 130 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS D 400 FOOT HEAD 173 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange
3.	76	6 00	4	4	⅝	39	13 0	168	5 8	.42	14 6	188	6 3	.45	15 5	199	6 6	.48	16 4	211	7 1
4	100	7 50	5	4	⅝	.42	18 0	234	9 0	.45	20 1	259	9 1	.48	21 3	275	9 7	.52	22 8	295	10 4
6	150	9 50	8	¾		.44	27 9	358	11 8	.48	27 3	398	12 3	.51	32 9	421	12 5	.55	35 3	451	13 7
8	200	13 50	11 75	8	¾	.46	38 7	498	16 9	.51	42 7	549	18 2	.56	48 0	614	19 0	.61	51 2	654	20 1
10	250	16 00	14	25	12	.50	51 9	671	23 9	.57	58 8	759	26 6	.62	65 5	840	27 3	.68	71 4	916	29 6
12	300	19 00	17 00	12	⅞	.54	67 0	876	35 8	.62	76 4	998	40 4	.68	85 4	1109	42 0	.75	93 7	1216	45 6
14	350	21 00	18 75	12	1	.57	82 3	1070	41 4	.66	94 7	1231	47 3	.74	108 1	1397	49 6	.82	119 2	1539	54 5
16	400	23 50	21 25	16	1	.60	98 8	1290	52 5	.70	114 6	1495	60 1	.80	133 3	1727	63 9	.90	147 5	1910	70 2
18	450	25 00	22 75	16	1⅛	.64	118 3	1528	54 5	.75	137 5	1770	62 5	.87	162 4	2083	66 9	.96	178 4	2257	73 4
20	500	27 50	25 00	20	1⅛	.67	137 4	1783	66 8	.80	163 1	2114	78 7	.92	190 6	2454	83 3	1 01	212 3	2731	92 1
24	600	32 00	29 50	20	1¼	.76	186 2	2424	92 9	.89	217 3	2821	106 8	1 04	257 6	3321	117 7	1 16	286 0	3686	126 9
30	750	38 75	36 00	28	1⅜	.88	266 1	3486	146 1	1 03	312 6	4077	162 9	1 20	366 9	4759	174 1	1 37	421 2	5436	191 0
36	900	46 00	42 75	32	1½	.99	358 7	4748	221 9	1 15	418 9	5541	215 2	1 36	497 7	6519	273 3	1 54	581 9	7577	296 8
40	1000	50 75	47 25	36	1½	1 06	427 2	5684	279 1	1 23	497 0	6586	311 2	1 48	601 6	7921	350 7	1 72	703 4	9203	349 0
42	1050	53 00	49 50	36	1¾	1 10	464 6	6195	310 0	1 28	542 2	7195	346 1	1 54	657 4	8660	385 3	1 78	761 1	10004	417 5
48	1200	59 50	56 00	44	1¾	1 26	608 0	8112	408 1	1 42	687 2	9132	442 9	1 71	832 7	10979	493 4	1 96	960 8	12578	524 3

Cast Iron Flanged Pipe

(Continued)

Nominal Diameter Millimeters	Nominal Diameter Inches	Diameter of Flange, Inches	Number of Bolts	Diameter of Bolts, Inches	CLASS E 500 FOOT HEAD 217 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS F 600 FOOT HEAD 260 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS G 700 FOOT HEAD 304 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange	CLASS H 800 FOOT HEAD 347 POUNDS PRESSURE Th'kness Ins.	Weight, Pounds per Foot	Length	Single Flange
6	150	11 50	9 50	8	¾	.58	37 7	495	21 3	.61	39 5	519	22 2	.65	42 9	560	22 9	.69	45 2	591	24 1
8	200	15 00	13 00	12	⅞	.60	54 7	718	31 2	.71	60 6	794	33 1	.75	65 1	849	33 9	.80	68 8	897	36 0
10	250	17 50	15 25	16	1	.74	78 5	1032	43 5	.80	84 7	1109	48 5	.86	92 5	1207	47 9	.92	98 5	1284	51 0
12	300	20 30	17 75	16	1⅛	.82	104 2	1375	64 0	.89	112 4	1487	68 5	.97	124 6	1630	71 6	1 01	132 5	1748	76 1
14	350	23 00	20 25	20	1⅛	.90	133 2	1762	82 7	.99	146 2	1935	90 0	1 07	160 2	2108	92 8	1 16	172 6	2271	100 0
16	400	25 50	22 50	20	1¼	.98	165 0	2192	106 0	1 08	180 8	2398	114 2	1 18	199 2	2627	116 6	1 27	215 0	2834	127 1
18	450	28 00	24 75	24	1⅛	1 07	202 3	2680	126 3	1 17	219 8	2915	138 8	1 28	244 6	3230	147 1	1 39	264 1	3488	159 0
20	500	30 50	27 00	24	1⅜	1 15	241 1	3200	153 4	1 27	262 5	3487	168 3	1 39	294 4	3894	180 7	1 51	318 3	4210	195 4
24	600	30 00	32 00	24	1¼	1 31	328 5	4431	244 3	1 45	361 6	4877	268 0	1 75	446 2	5413	295 0	1 88	476 9	6355	316 0
30	750	43 00	39 00	28	1⅞	1 55	484 7	6534	358 5	1 73	538 0	7265	405 2								
36	900	50 00	46 00	32	1⅞	1 80	674 2	9167	538 5	2 01	748 7	10040	577 8								

NOTE.—Thickness of flange equals approximately 1¼ times thickness of pipe plus ⅛ in. Flanges drilled to "American 1914 Standard" Templates. *In ordering,* if special drilling be required, a template of such drilling should be furnished to avoid mistakes. Bolt holes drilled 1⁄19 in. larger than bolts. All dimensions in inches. Pipe made in 12 ft. lengths and faced 1⁄16 in. short for gaskets; special short lengths are made to order. In the table are neat finished weights. Allowance must be made for variation and finish. All weights are approximate.

Riveted Steel Pipe.—Large pipes are frequently made up of steel plates with riveted joints, the seams being either longitudinal and circumferential, or spiral.

SPIRAL RIVETED FLANGED PIPE
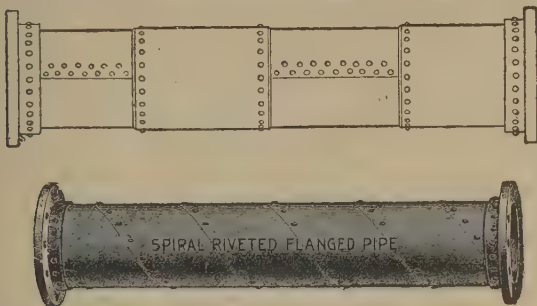
Figs. 6,066 and 6,067.—Straight and spiral riveted steel pipe.

NOTE.—*Butt welding process.* A certain natural flux is essential to the proper welding of pipe, as the edges must be free of foreign matter to allow full and immediate contact of clean metal. A flux of this nature forms on the skelp in the welding furnace and in a molten condition covers the edges of the pipe. When the skelp is drawn through the welding bell the molten flux is entirely pushed aside as the clean metal of the edges of the pipe is brought together under great pressure. This results in a sound weld. The molten flux is partly scraped off the outer surface of the pipe by the welding bell, but the interior of the pipe, not coming in contact with the bell, remains irregularly covered, rather thickly in spots. This flux soon hardens and forms mill scale. The desirability of removing this mill scale, or welding scale, has resulted in the use of a special treatment by rolling when making butt weld pipe, as follows, sizes ½ in. to 3 ins. When the skelp has reached the proper temperature for welding, it is drawn through the customary type of welding bell forming an unfinished tube. This tube then passes through a set of rolls where it is reduced slightly in size and elongated. In this operation, the welding scale which has formed is partially loosened by the working of the rolls, but further special treatment is necessary to secure the desired result. From the sizing rolls the pipe is conveyed to a cooling table across which it travels to the scaling rolls. It is the nature of the welding scale to harden somewhat more quickly than the pipe metal, and while the pipe is still soft and hot and the scale is in a hardened and brittle condition t is given a pass through a series of rolls of special design. These rolls reduce the size of the pipe somewhat, crush the pipe down slightly and roll the pipe to its correct finished size. The reduction in the size of the pipe which it received in passing through the series of roll cracks the hardened welding scale from both the interior and exterior surfaces of the pipe, leaving them clean and smooth. From these scaling rolls, the pipe moves to another cooling table where it is kept slowly rolling as it travels across, straightening somewhat as it cools. After a pass through a set of cross rolls, to take care of any straightening that may remain to be done and to give the exterior a smooth clean finish, the pipe is taken to a tank of water where it is dipped, lifted to a slanting position and the water allowed to rush out, carrying with it the loose scale from the pipe. Certain sizes have the loose scale blown out by a blast of compressed air instead of being dipped in the water. The pipe is trimmed, threaded and tested in the usual manner of all butt weld pipe.

Riveted pipe is frequently used in large hydraulic installations where the ordinary pipe sizes would be of insufficient capacity for the volume of water passing through them.   The helical seam riveted pipe was invented by John B. Root, and by him termed "spiral riveted pipe."

The helical seam makes it possible to obtain in a riveted pipe practically the full strength of the plate, whereas with a longitudinal riveted seam, 60 to 65 per cent. of the strength of the plate is all that is usually obtained. They may be joined by flanges of cast or pressed steel.   These flanges are
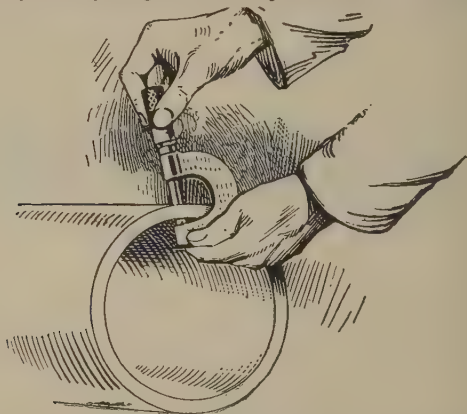
FIG. 6,068.—*Gauging wall thickness of large hot drawn tube.* Hot drawn tubing is extensively used in place of castings, forged parts and solid stock. The physical properties of the material and the relatively large diameters and range of wall thicknesses adapt it for such uses as formed axle housings, shaft casings, cylinders, columns and pistons of hydraulic and other apparatus, compressed air containers, retorts, gear ring blanks and for other purposes where hot finished or cold drawn tubing would be unsuitable because of limitation of size, gauge, and possible extra cost of the latter class of materials in large quantities. Hot drawn material will stand an unusual amount of manipulating, such as expanding, swaging, upsetting and flanging.

riveted to the ends of the pipe.   The riveted ends are caulked, and then the pipe is generally galvanized.

Copper Pipes.—The use of copper pipes for steam mains is not so common at present as formerly, and *their use for such service should be discontinued*, as with the exception of its great ductility and ease with which complicated forms may be built

up from small sheets joined by brazing, there is nothing to recommend them, but much to condemn.

Copper pipes do not have the strength of wrought iron or steel pipes, and what little strength they possess is rapidly reduced at high temperatures; moreover, the brazed joint is unreliable, rendering the actual bursting strength of the pipe an unknown quantity.

The difficulty with a brazed joint lies in the fact that copper, if heated up to nearly its melting point during the brazing operation, loses its strength, becoming weak and brittle. When in this condition the copper is called "burnt."

At a temperature of 360° Fahr., its strength is reduced 15 per cent., and on this account it should never be used for high steam pressures and temperatures; at 800° to 900° its strength is reduced about one half. Although copper does not corrode, it exercises a very destructive galvanic action upon iron and steel, if immersed together in a polarizing liquid, and is, therefore, not a desirable material on steel hulls, in places reached by salt water or bilge.

Brass Pipe.—The advantage of brass pipe is that it does not rust or corrode, but in cost, is very expensive as compared with iron pipe. It is made in iron pipe sizes and is tested to a pressure of 1,000 pounds per square inch before shipment.

The temper of the brass is not strictly hard, but just sufficiently annealed to prevent cracking and to make it suitable for steam work.

Brass pipe is made by the seamless process. It comes in 12 foot lengths, up to 4 inches diameter.

Lead Pipe.—The advantages of lead pipe in plumbing are: 1, its superior rust resisting property; 2, ease with which it can be bent around corners, making fittings and joints unnecessary.

Tubes.—The difference between a tube and a pipe is not generally understood, but should be by any mechanic desiring to be well informed. In distinction, a tube has relatively

thin walls and the listed sizes correspond to the outside diameter; a pipe has relatively thick walls and the listed sizes of wrought pipe do not correspond to the outer diameter. The following properties of a 1 in. tube and 1 in. wrought pipe will clearly illustrate the distinction *between tubes and pipes.*

Properties of One In. Tube and Pipe

	Outside Diameter, Ins.	Inside Diameter, Ins.	Thickness of Metal, Ins.
1 in. tube......................	1	.81	.095*
1 in. wrought pipe...............	1.315	1.049	.135

*The thickness .095 here given is the standard thickness for 1 in. boiler tube and corresponds to No. 13 *B w. g.*

CHAPTER 107

Tools

On ordinary jobs only a few tools are required by the plumber, but for all the operations performed in plumbing work, broadly considered, a considerable number are required.   In this chapter only the ordinary or commonly used tools are considered, additional and special tools being shown in the chapters treating of the work for which they are used.

With respect to use, plumbers' tools may be classified as:

1. Guiding and testing tools.

   a. Straight edge.
   b. Square.
   c. Level.
   d. Plumb bob.

2. Marking tools.

   a. Chalk line.
   b. Pencil.
   c. Scratch awl.
   d. Scriber.
   e. Compasses and dividers.

3. Measuring tools.

   a. Rule.
   b. Tape.

4. Holding tools.

- *a*. Pliers.
- *b*. Clamps.
- *c*. Vises.

5. Toothed cutting tools.

- *a*. Saws.
- *b*. Files.
- *c*. Rasps.

6. Scraping tools.

- *a*. Scrapers.
- *b*. Sand paper.

7. Sharp edge cutting tools.

- *a*. Chisels.
- *b*. Cold chisels.
- *c*. Knife.
- *d*. Wire cutters.
- *e*. Shears.
- *f*. Hatchet

8. Boring tools.

- *a*. Gimlets.
- *b*. Bits.
- *c*. Drills.
- *d*. Countersinks.
- *e*. Reamers.
- *f*. Tap borer.

9. Threading tools.

- *a*. Dies.
- *b*. Taps.
- *c*. Stocks.
- *d*. Pipe vise.
- *e*. Pipe cutters.

10. Fastening tools.

   a. Hammers.
   b. Screw drivers.
   c. Wrenches.

11. Bending tools.

   a. Hickey.
   b. Bending pins.
   c. Dummy.
   d. Sand plugs.
   e. Bobbins.

12. Forming tools.

   a. Dresser.
   b. Bossing stick.

13. Soldering and jointing tools.

   a. Bits.
   b. Solder pot.
   c. Ladle.
   d. Tank iron.
   e. Wiper.

14. Heating tools.

   a. Fire pots.
   b. Torches.

15. Cleaning tools.

   a. Force cups.
   b. Augers.

<div align="center">etc., etc.</div>

From the list it will be seen that the work of the plumber overlaps that of the carpenter somewhat; in fact, a good all-round plumber should also be a second rate carpenter, because

the roughing out work for the reception of the piping and fixtures, though usually done by a carpenter, must sometimes be done by the plumber, especially in remote sections.

FIG. 6,069.—Plumber's tool bag, reinforced with leather bottom and sides.
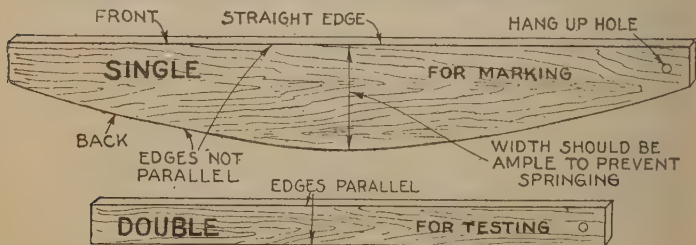
FIG. 6,070.—Ordinary single wooden straight edge for marking. When well made it is sufficiently accurate for ordinary use. *In making* a straight edge of this kind, clear, straight grained wood should be used. The back edge should not be parallel with the front because there should be greater width at the center than at the ends for stiffness, the width at the center depending upon the thickness. The length may range from a few inches to several feet, depending upon the intended use.

FIG. 6,071.—Ordinary double wooden straight edge for testing. This differs from the single straight edge in that both front and back edges are parallel so that it may be used for special tests such as for winding surfaces.

The tools ordinarily carried by the plumber to the job are very few and the practice of going to work with a half filled kit and ringing up time on the customer while the helper goes back to the shop for those needed, will not be tolerated by an honest employer.

Straight Edge.—This tool is used to guide the pencil or scriber in marking a straight line, and in testing a faced surface as the edge of a board to determine if it be straight. Anything
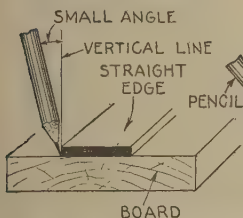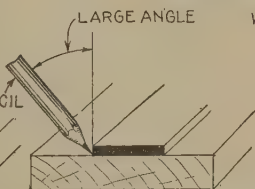
Figs. 6,072 to 6,074. —*Right and wrong inclinations* of the pencil in marking with the straight edge. In fig. 6,072 the pencil should not be inclined from the vertical more than is necessary to bring the pencil lead in contact with the guiding surface of the straight edge. When inclined more as in fig. 6,073, and the pencil pressed firmly, considerable pressure is brought against the straight edge, tending to push it out of position. If the inclination be in the opposite direction, as in fig. 6,074, the lead recedes from the guiding surface introducing an error which is magnified when a wooden straight edge is used because of the excess thickness of the straight edge.

having an edge known to be straight, as the edge of a steel square may be used, however, a regular straight edge is preferable.

It may be made either of wood or steel and in length from a few inches to several feet. For ordinary work a plumber can make one sufficiently accurate from a strip of good straight grained wood, but for accurate work a steel straight edge should be used. Wood is objectionable in work of precision because of its tendency to warp or spring out of shape.

Square.—This tool is *a 90° or right angle standard* and is used for marking or testing work. There are several types of square as:

1. Try (or trying) square.
2. Combined try and mitre square.
3. Combination square.
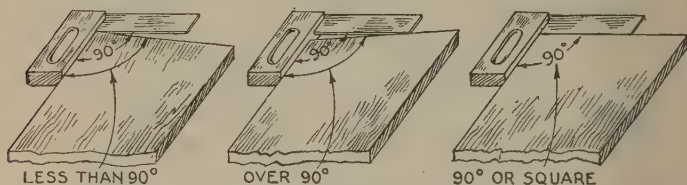
FIGS. 6,075 to 6,077.—Application of try square for testing end of board to determine if th · cross cut be "square" with longitudinal edge of board. Figs. 6,075 and 6,076 show end edge at angles less and greater than 90° and fig. 6,077, end edge at 90° or "square."
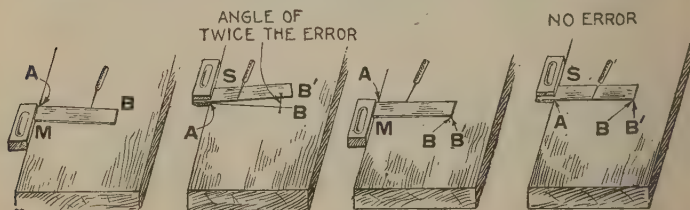
FIGS. 6,078 to 6,081.—Method of testing a try square. If square be "out" (angle not 90°) scribed lines AB, and AB′, for positions M, and S, of square (figs. 6,078 and 6,079) will not coincide. Angle BAB′, is twice the angle of error. *Why?* If square be correct, AB, and AB′, for positions M, and S, will coincide as in figs. 6,080 and 6,081.

Try Square.—In England this is called the *trying square* but here simply *try square*. It is so called probably because of its frequent use as a testing tool when squaring up mill planed stock. The ordinary try square used by carpenters consists of a steel *blade* set at right angles to the inside face of the *stock* in

which it is held. The stock is made of some hard wood and is always faced with brass in order to preserve the wood from injury.
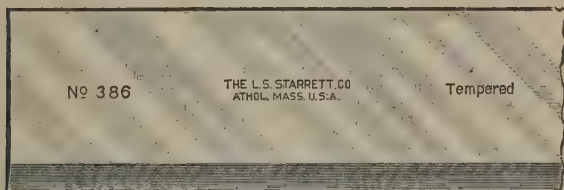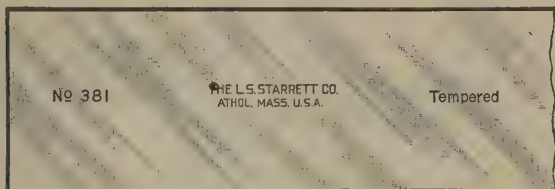
Figs 6,082 and 6,083.—Starrett steel straight edges. Fig. 6,082, plain; fig. 6,083, beveled. The straight edges are nickel plated and while they are intended especially for draughtmen's work, they can be used to advantage by plumbers on work of precision. Made in lengths ranging from 12 to 72 ins.; width 1⅜ to 2½; thickness ⁵⁄₆₄ to ⅞₄.

NOTE.—*Steel straight edges.* Where lines are to be scribed straight or when surfaces must be tested for their precision, an accurate standard edge is generally used. Straight edges are also necessary on some kinds of work for use in sighting for winding It is needless to say that such straight edges must be absolutely dependable.

NOTE.—*Shrinkage rules.* For all ordinary measurements a standard rule is used, but for laying out or for working patterns, or any part of a pattern or core box, a shrinkage rule should be used. The reasons are that when a mould made from the wooden pattern in the sand is filled with molten metal, its temperature is very high, and as it cools and solidifies it contracts. Accordingly to compensate for this, the pattern maker must add to the size of the pattern. In order that this may be done and exact relations be maintained for all dimensions a shrinkage rule is used. This rule is graduated like an ordinary rule, but if the two are compared the shrinkage rule will be found to be longer. *Example:* Cast iron will shrink about ⅛ in. to the foot, so the rule in reality would be 12⅛ ins. long, the additional length gradually being gained in the length of the rule. The contraction of different metals in the moulds varies greatly, that for cast iron being about ⅛ in. to each foot, ³⁄₁₆ in. to the foot for brass, while for many of the softer metals it is as great as ¼ in. to the foot.

The usual sizes of try squares have blades ránging fron 3 to 15 inches long. The stock is about ½ inch thick with blade inserted midway between the sides of the stock. The stock is made thicker than the blade so that its face may be applied to the edge of the wood and the steel blade laid on the surface to be marked. Usually the blade is provided with a scale of inches divided into 8ths.
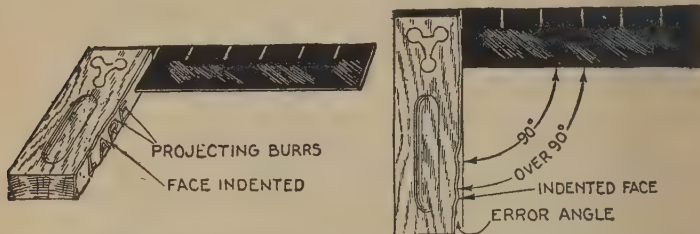
FIGS. 6,084.—One way to ruin a good try square: *stamp your initials all over the brass face plate of the stock*. Place the square in a vise or preferably lay it on an anvil with brass face up. With stencils and a heavy hammer stamp the letters deep so all can see them—using sufficient force to thoroughly test the compression strength of the wood and brass.

FIG. 6,085.—Result obtained by stenciling initials on the brass plate of a try square. Note the projecting burrs and indented surface of the face, both of which tend to throw the square out of truth or even cause it to wobble when pressed against the edge of a board.
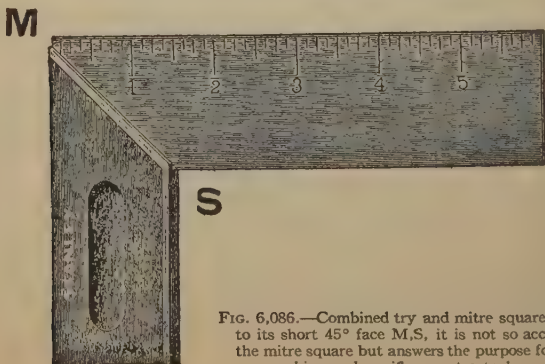
FIG. 6,086.—Combined try and mitre square. Owing to its short 45° face M,S, it is not so accurate as the mitre square but answers the purpose for ordinary marking and avoids an extra tool.

Mitre, and Combined Try and Mitre Squares.—The term *mitre*, strictly speaking, signifies any angle except a right angle, but as applied to squares it usually means an angle of 45°.

In the mitre square the blade as in the try square is permanently set, but at an angle of 45° with the stock.
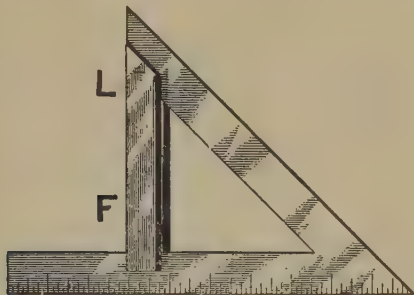
FIG. 6,087.—Improved form of combined try and mitre square.
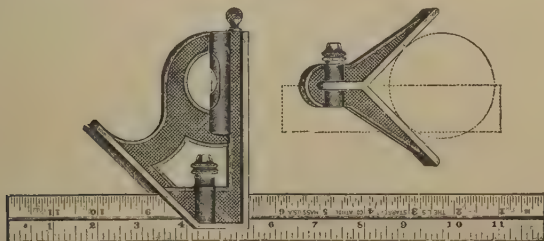
FIGS. 6,088 and 6,089.—Starrett combination square with hardened blade, level and centering attachment.

A try square may be made into a combined try and mitre square, when the end of the stock to which the blade is fastened is faced off at 45° as along the line MS in fig. 6,086. In use, when

the 45° face MS, of the stock is placed against the edge of a board, the blade will be at an angle of 45° with the edge of the board.

Level.—This tool is used for both guiding and testing; to guide in bringing the work to a horizontal or vertical position,

LEVEL GLASS   PLUMB GLASS

— 12 TO 30 INS. —
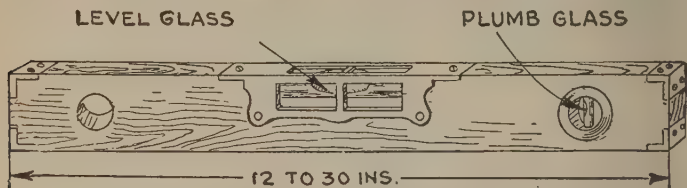
Fig. 6,090.—Wooden spirit level having horizontal and vertical tubes. The body of the level is made of some hard wood, as rose wood, and is preferably provided with brass mountings as shown.

BUBBLE   F   ANGLE OF ERROR
M   L   S   B
A
TUBE
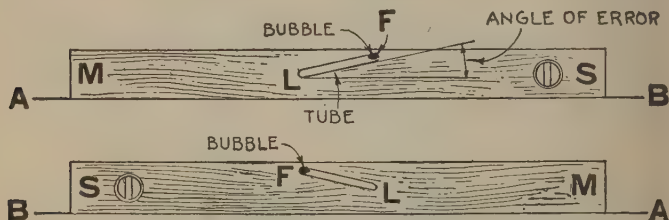
BUBBLE
S   F   L   M
B   A

Figs. 6,091 and 6,092.—How to test a spirit level. Lay level on a horizontal surface as A,B, in fig. 6,091. If one end of tube as F, be high, the bubble will run to that end. Reverse level from position M,S, fig. 6,091, to position S,M, fig. 6,092, and it will be found that the bubble will remain at the high end. That is, in fig. 6,091 the bubble is seen at the right, and in fig. 6,092, at the left. *In adjustable levels* this error is easily corrected. When the adjustment has been correctly made, the bubble will remain at the center of the tube for both positions of the level when placed on a horizontal surface.

and to test the accuracy of completed construction. It consists of a long rectangular body of wood or metal cut away on its side and near the end to receive glass tubes which are almost entirely filled with a non-freezing liquid which leaves a small bubble free to move as the level is moved.

The side and end tubes are at right angles, so that when the bubble of the side tube is at the center of the tube, the level is horizontal; when the bubble of the end tube is at the center the level is vertical. Accordingly by holding the level on a surface supposed to be horizontal or vertical, it may be ascertained if such surfaces be horizontal or vertical.

Plumb Bob.—The word *plumb* means *perpendicular to the plane of the horizon*, and since the
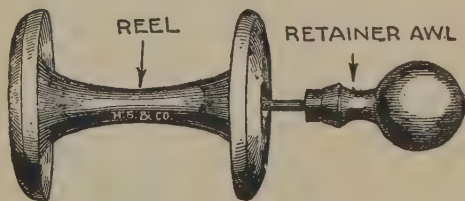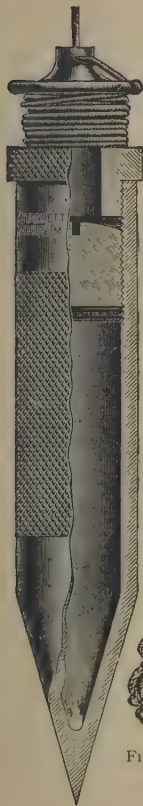
FIG. 6,094.—Chalk line reel bored to receive the line retaining awl. The chalk line is wound on the reel when not in use and the awl inserted into reel as shown.

FIG. 6,095.—Chalk line. It can usually be obtained as follows: braided, 84 ft. hanks; cotton, light or heavy, 20 ft. hanks; Mason's linen, light, 84 ft. and heavy, 50 ft. hanks; Mason's cotton, 450 to 600 ft. per lb. hank.

FIG. 6,093.—Starrett mercury plumb bob. *It is made* from solid steel, bored and filled with mercury. The features of this design are: great weight in proportion to size, low center of gravity, small diameter, hardened and ground point, knurled body, and fastening device. By drawing the line into the peculiarly slotted neck at the top, after unwinding the required length, the bob will hang true.

plane of the horizon is perpendicular to the direction of gravity at any given point, the force due to gravity is utilized to obtain a vertical line in the device known as a plumb bob as shown in fig. 6,093.

Chalk Line and Reel.—The special use of this device is to mark a long straight line between two points too far distant

RIGHT WAY   **WRONG WAY**
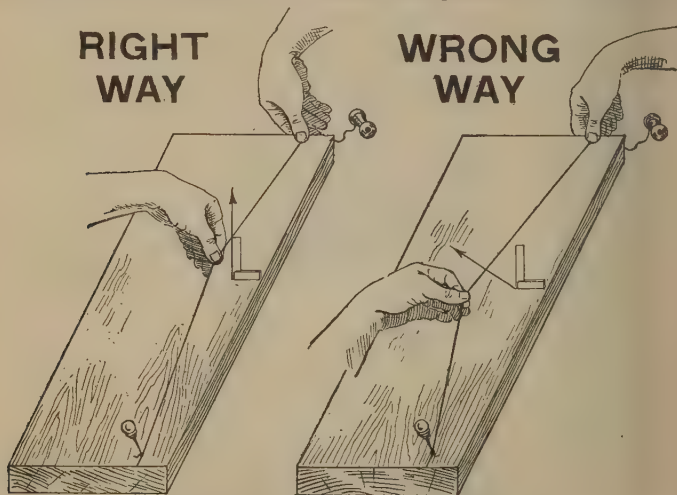
Figs. 6,096 and 6,097.—*Right* and *wrong* way to use the chalk line. *In pulling up the line always pull it up in a direction at right angles with the board—not to one side.*

to permit the use of a square or straight edge as for instance in marking a long plank for the rip saw.

The line consists of a light string or cord.

It is rubbed with chalk and then stretched between the two points. When the string is taut, it is pulled up and let spring back, thus marking a white line on the surface of the work. In using a chalk line, note the right and wrong way to use the line as shown in figs. 6,096 and 6 097.

Ordinary Pencil.—This form of pencil with its cylindrical lead is familiar to all and needs no description. Since the lead is smaller than that of the carpenter's pencil it produces a finer lead. It is used on smooth surfaces where more accurate marking is required than with the carpenter's pencil. In using, the best results are obtained by twisting the pencil while drawing the lines so as to retain the conical shape given the

Fig. 6,098.—Ordinary carpenter's pencil showing shape of the large lead.

ACRE OF LEAD

PROPER CONDITION
OF POINT
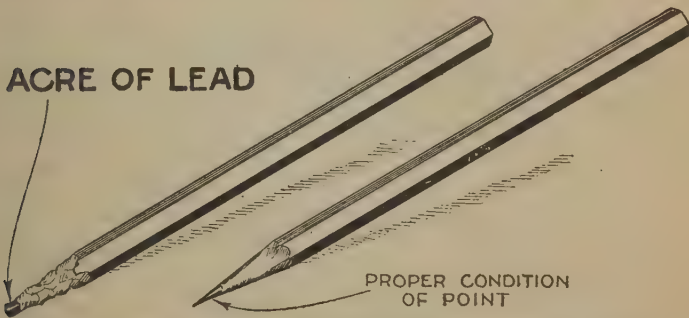
Figs. 6,099 and 6,100.—Usual condition of lead pencil and proper condition. How can you expect to lay out work accurately with a lead pencil having "an acre of lead" on its point.

lead in sharpening. Do not expect to lay out work accurately with a lead pencil having *"an acre of lead" on its point*.

Marking or "Scratch" Awl.—This consists of a short piece of round steel, pointed at one end and the other end fixed in a convenient handle. A scratch awl is a *cheap form of scriber* and

is used in laying out fine work where a lead pencil mark would be too coarse for the required degree of precision.

Scriber.—This is a tool of extreme precision and while intended especially for machinists, it should be in the tool kit of

FIG. 6,101.—How to sharpen a pencil. Hold the pencil firmly in the left hand, as in the drawing, allowing about an inch to project beyond the fingers, and turn it gradually as the knife removes the wood. The knife should be held so that the blade alone projects beyond the fingers, and the part of it nearest the handle used for cutting. The pencil should be placed against the inside of the thumb of the right hand, as shown, and the wood removed by slight shaving. The lead should not be cut at the same time as the wood, but rested on the thumb and pared gently afterwards; by attention to these directions the pencil will be economized.

FIG. 6,102.—Ordinary scratch awl forged blade and hardwood handle.

FIGS. 6,103 and 6,104.—Starrett pocket scriber, showing scriber in open and closed positions. The stock or handle is made from steel tubing knurled and nickel plated. The scriber or blade is of steel, tempered, and is held by a knurled chuck. The scriber is reversible, telescoping into the stock, and is held by a slight turn of the chuck so that the point is protected inside the stock when not in use as in fig. 6,104.

all mechanics who make any claim to being skilled in their occupation.

A scriber is *a hardened steel tool with a sharp point designed to mark very fine lines.*

The most convenient form of scriber is the pocket or telescoping type shown in figs. 6,103 and 6,104, the construction rendering it safe to carry in the pocket.
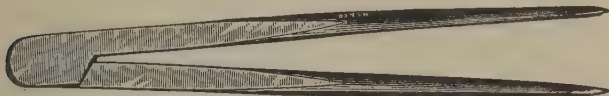
Fig. 6,105.—Compasses. This tool should be used simply for describing arcs or circles and not for *dividing*, especially where a given arc or line is to be divided into many parts because an extremely small error in the setting will make a big error in the last division.
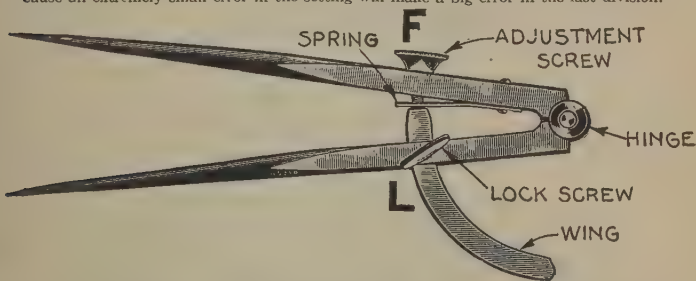
Fig. 6,106.—Winged dividers for describing and dividing arcs and circles. Evidently when the dividers are locked to the approximate setting by lock screw **L,** the tool can be set with precision to the exact dimension by turning adjustment screw **F,** against which the leg is always firmly held by the spring which prevents any lost motion.

Compasses and Dividers.—The tool called *compasses* is *an instrument used for describing circles or arcs by scribing.* It

NOTE.—The difference between *dividers* and *compasses* is that the dividers is provided with a quadrantal wing projecting from one of the two hinged legs through a slot in the other. A set screw on the slotted leg enables the instrument to be securely locked to the approximate dimension and adjusted with precision to the exact dimension by a screw at the other end of the wing. A spring pressing against the wing holds the leg firmly against the screw. Its general appearance is shown in fig. 6,106. Because of the wing the tool is frequently called *winged* dividers

consists of two pointed legs hinged firmly by a rivet so as to remain set in any position by the friction of the hinged joint. The usual form of compasses is shown in fig. 6,105, and it should not be used instead of dividers for dividing an arc or line into a number of equal divisions because it is not a tool of precision.
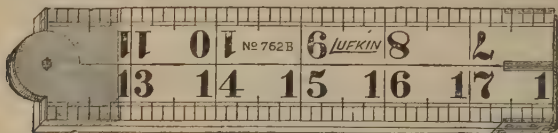
FIG. 6,107.—Lufkin two foot four fold boxwood **blind man's** rule with square joint, edge plates, unbound. Graduations: 8ths and 16ths. The large and distinct figures are especially adapted for use in poorly lighted places, or by persons with poor eye sight.
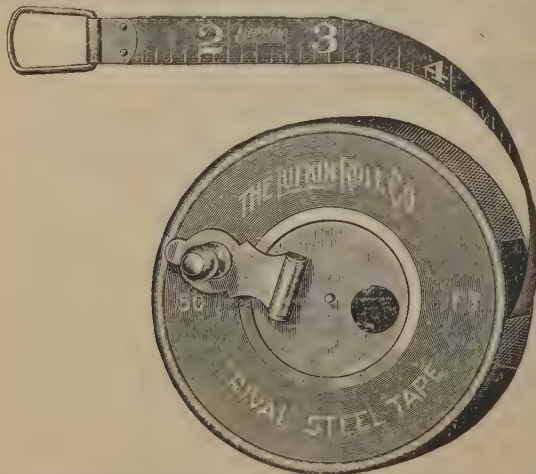
FIG. 6,108.—Lufkin "Rival" steel measuring tape, folding flush handle, opened by pressing pin on opposite side. Cases have knurled edges, which afford a firm hold when winding in tape.

NOTE.—The *inertia method of setting dividers* as employed by machinists, of hitting one leg of the dividers against the work, cannot be practiced in carpentry because of the soft and yielding nature of wood.

Ordinary Two Foot Rule.—This is a most familiar form of rule and is usually made *four fold*, that is with three hinges spaced 6 inches apart and so arranged that it can be folded up.

For plumbers who do most of their work inside, usually in dark places, a so-called blind man's rule as shown in fig. 6,107 is a desirable form.

Clamps.—Frequently it is necessary to tightly press pieces
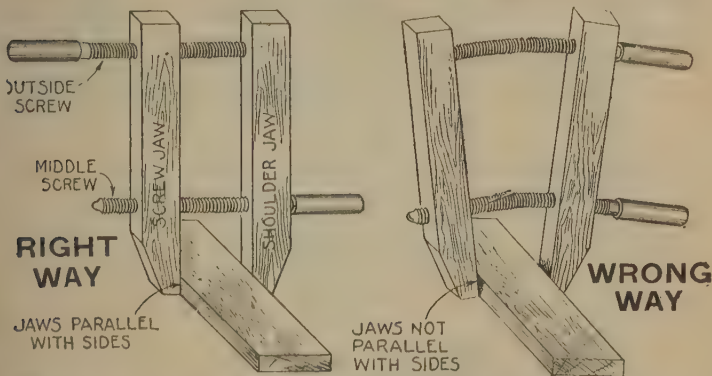
Figs. 6,109 and 6,110. —All wood clamps or hand screws showing *right and wrong way* to use them. *In using,* first set jaws to nearly the size of the material to be clamped. In placing the hand screws upon the work, the outside screw should be turned back so that it will not prevent the jaws being slightly closer at the outside screw than at the points. This will allow the strain which is applied in setting up the outside screw *to bring the jaws parallel, which is the only position in which they should be when clamping the work.* Since the screws are made of wood instead of iron *use some judgment and not apply too much pressure.*

of wood together that may have been mortised and tenoned, grooved and tongued, or simply glued. The bench vise is not always a convenient tool for this purpose, clamps as shown in the accompanying illustrations being more desirable.

Vises.—The essential features of a vise are rigidity, weight,

strength, accurate fit and smoothly working parts. The vises here considered are iron vises.

Rigidity and weight are required to make effective the effort expended on the work held in the vise. The "anvil quality," or inertia sufficient to
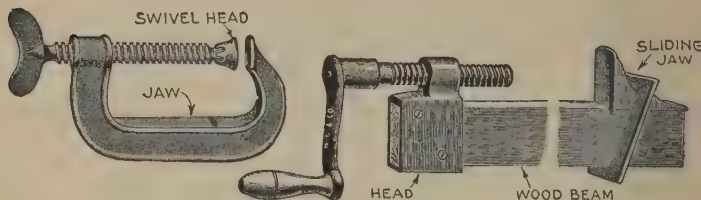
FIG. 6,111.—Single screw malleable iron jaw clamp with swivel head on screw. Ordinary range of sizes have openings from 2 to 10 ins.

FIG. 6,112.—Wood beam clamp. By purchasing the iron fixtures for this clamp the carpenter can make the arm any length desired, most convenient for his work. It is not only a door clamp but may be used for holding any piece of glued work that will fit between its jaws.
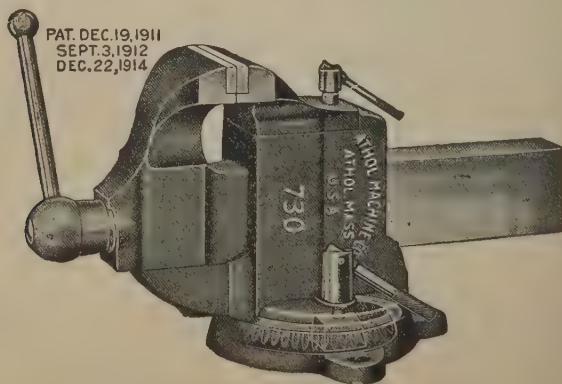
FIGS. 6,113.—Athol(Starrett's) vise with self-adjusting jaw and swivel bottom and adjustable handle.

effectively hold a piece of work solidly against a blow, is a most important qualification in a vise, and a suitable mass of iron is just as necessary to supply this inertia as to supply strength against rupture. It is, of course, essential that a vise be strong enough to withstand any strain that may be legitimately put upon it.

FIGS. 6,114 to 6,121.—Disston handy saw kit containing key hole, compass, cross cut, rip, saws, etc.

NOTE. –*Vise abuse.* There is probably no tool in a shop subjected to more abuse than a vise. A fruitful cause of breakage is the clamping near one end of a long piece of work which may thus have considerable overhang. Many times the operator, instead of hunting up a stick or other support to keep the free end from dropping, will attempt to hold it by excessive pressure between the vise jaws; and if in that condition the operation may involve any considerable hammering, the service exacted of that vise is most severe. One cause of a minor breakage is the clamping of a hard piece of metal so that the pressure is concentrated upon a small area near the margins or corners of the hardened jaw face; and if the jaw be hardened enough to resist battering or indentation, a piece is almost sure to be broken out, leaving an unsightly notch. A very common fault with vise users is the failure to keep the screw lubricated. The thread on many vise nuts has practically disappeared from this cause. The front jaw should be occasionally detached from the vise, turned over, and the screw lubricated its entire working length. When this is done at reasonable intervals, the screw and nut will wear indefinitely. The use of vises having smooth faces for their gripping jaws is not nearly as extensive as it would be with a better comprehension of their capabilities.

Saws.—There is an undue multiplicity of saws on the market. The plumber uses a kind of a saw of all work, for cutting wood, lead pipe and what not.

It has a blade about 16 ins. long, with coarse teeth on one side and fine teeth on the other. A nest of saws as shown in figs. 6,114 to 6,121 will be found useful for many odd jobs.
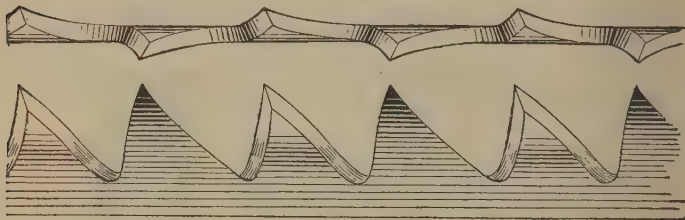
FIGS. 6,122 and 6,123.—Enlarged views of cross cut teeth showing their shape. In fig. 6,122 the teeth are seen looking on the cutting edge, which brings out in pronounced manner the "set" of the points on each side.
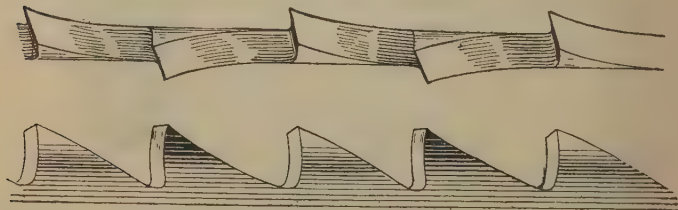
FIGS. 6,124 and 6,125.—Enlarged views of rip teeth showing their form of straight front or face and cutting edge square across the top. In fig. 6,124, the teeth are seen looking down on the edge, bringing out strongly the appearance of a series of chisel edges and the manner of "set." The square top and straight front are distinguishing features of the rip tooth.

Files and Rasps.—By definition, a file is a steel instrument, having its surface covered with sharp edged furrows or teeth, used for abrading or smoothing other substances as metal and wood.

A rasp is a very coarse file and differs from the ordinary file

in that its teeth consists of projecting points instead of V-shaped projections extending across the face of the file.

Files are used for many purposes by wood workers. Figs. 6,126 to 6,135 show a variety of files.

The taper file is adapted for sharpening hand, pruning, and buck saws.

SLIM TAPER

TAPER

SQUARE

BLUNT BAND

MILL

FLAT BASTARD

HALF ROUND

ROUND

HALF ROUND RASP

HORSE SHOE RASP
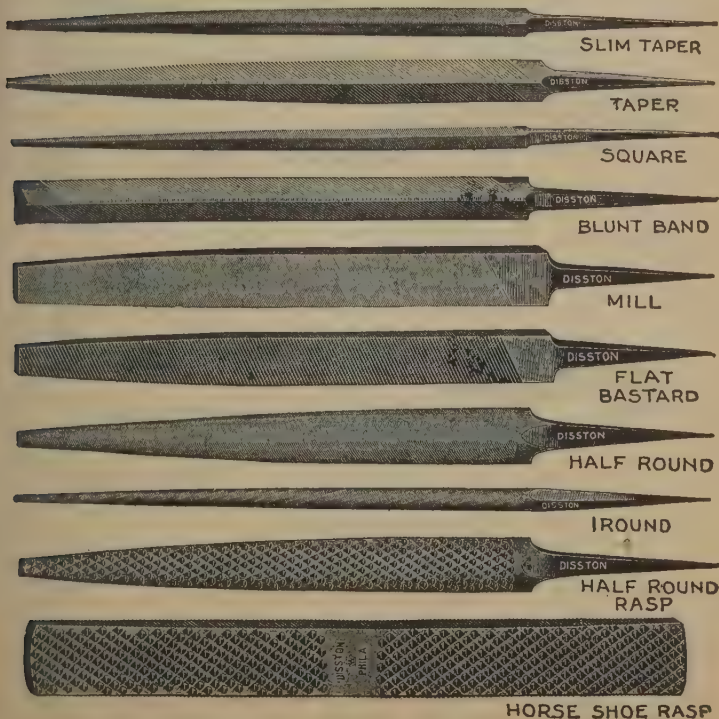
Figs. 6,126 to 6,135.—Various files and rasps.

The teeth of the mill file leave a smooth surface. They are particularly adapted to filing and sharpening mill saws, mowing and reaping machine cutters.

Rasps are generally used for cutting away or smoothing wood or for finishing off the rough edge left in a circular hole cut with the key hole saw. The ordinary wood rasp is rougher or coarser than that used by cabinet makers.
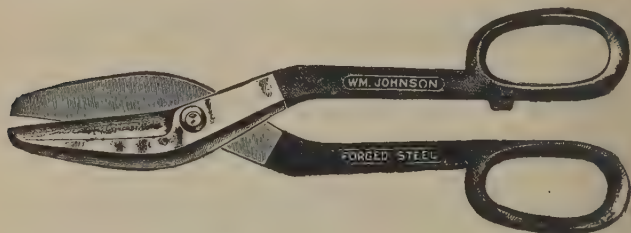
Fig. 6,136.—Tinner's snips, regular pattern.

Fig. 6,137.—Tinner's snips, circular pattern.

Sand Paper.—This consists of *tough paper covered with finely crushed abrading material.*

Sand paper is manufactured in rolls of about 1,000 yards in length and widths of from 24 to 48 inches. It is cut in sheets 9×11 inches and sold in reams of 480 sheets, or furnished in rolls of various widths such as 6, 8, 14, 24, 30, 36, 40, 42 and

48 inches containing 50 yards. It is made on paper made especially for the purpose from old manila rope which produces paper of the very greatest strength.

The ordinary sand paper designations are known by the numbers: 000, 00, 0, ½, 1, 1½, 2, 2½, 3, and 3½, reading from fine to coarse.

Fig. 6,138.—Bernz forged steel gas pliers.

Fig. 6,139.—Bernz gas main force pump. *In construction,* the pump barrel projects into an air reservoir; an ordinary size has a 2¼ × 16 in. pump and 7 × 18 in. reservoir.

Scrapers.—There are two kinds: those intended for wood, and those for metal. The particular kind of scraper mostly

used by plumbers is known as the *shave hook*, as shown in fig. 6,142. They are made in various shapes, the one shown being for general use in brightening metal surfaces, preliminary to soldering or wiping joints. Fig. 6,143 shows the method of using this tool.
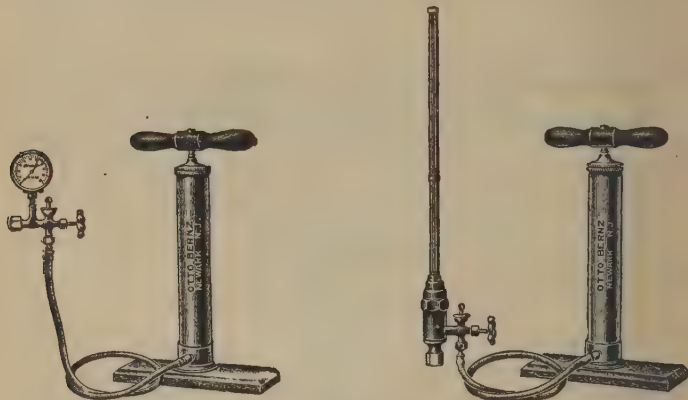
Fig. 6,140 and 6,141.—Testing pumps. Fig. 6,140, pump with air gauge, ether cock and hose; fig. 6,141, pump with regular old style mercury column and hose. Mercury column is fitted with a glass tube which is guarded by a brass shield. This shield is graduated for the convenience of the user. This style mercury column must be emptied after each job.
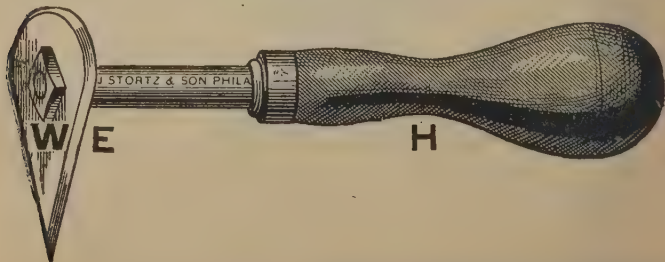
Fig. 6,142.—Shave hook. *It consists of* a steel blade **E**, beveled to an edge all around and secured to a convenient handle **H**, being fastened by the bolt **W**.

Chisels.—In carpentry the chisel is an indispensable tool. The plumber frequently must use the chisel in cutting away wood work to make room for pipes. A chisel should be absolutely flat on the back (the side not beveled). An inferior chisel is ground off on the back near the cutting edge, with the
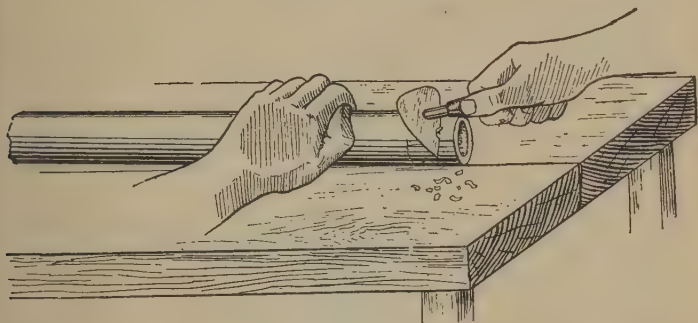
FIG. 6,143.—Method of using shave hook in scraping a lead pipe preliminary to making wiped joint.
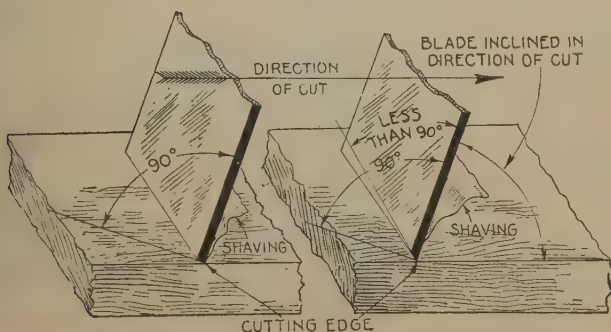
FIGS. 6,144 and 6,145.—Scraper with normal (90°) cutting edge and acute (less than 90°) cutting edge, showing position of scraper in cutting.

result that, in use, it tends to follow the grain of the wood, splitting it off unevenly, as the user cannot properly control his tool. The flat back allows the chisel to take off the very finest shaving, and where a thick cut is desired, it will not strike too deep. This is a point to be found in good chisels.
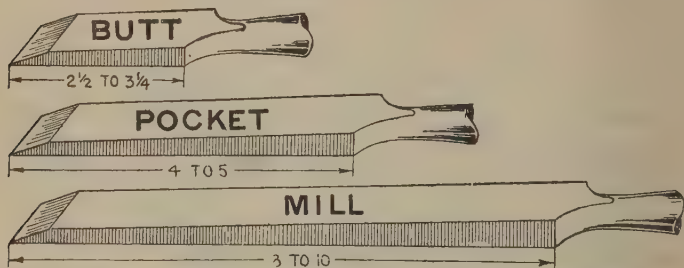
FIGS. 6,146 to 6,148.—Various chisels classified *with respect to length of blade.* Fig. 6,146, butt; fig. 6,147, pocket; fig. 6,148, mill, or millwright.
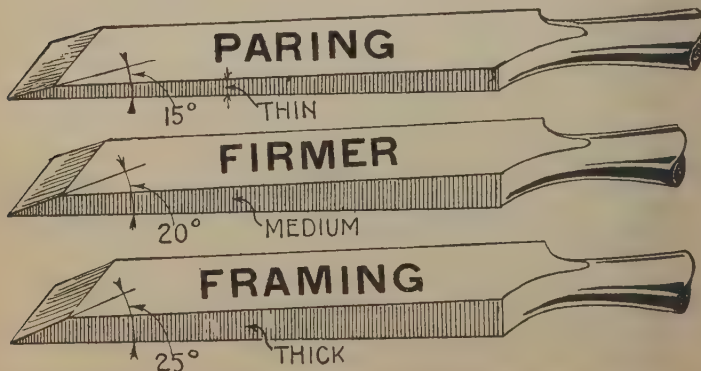
FIGS. 6,149 to 6,151.—Various chisels classified *with respect to duty.* Fig. 6,149, paring or light duty; fig. 6,150, firmer, medium duty; fig. 6,151, framing, heavy duty.

Fig. 6,153.—Ratchet testing plugs.
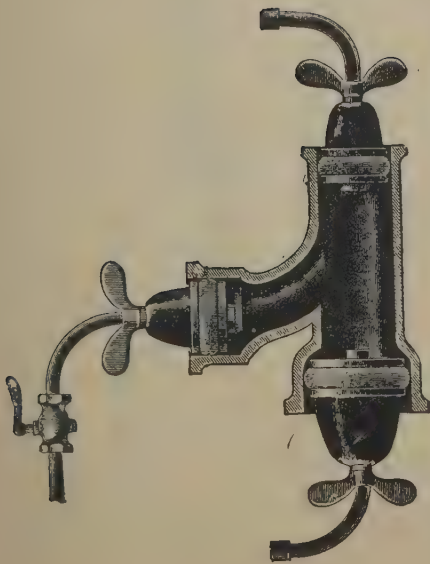
Fig. 6,152.—Wing nut testing plugs. The castings are of grey iron and the pipe of steel.
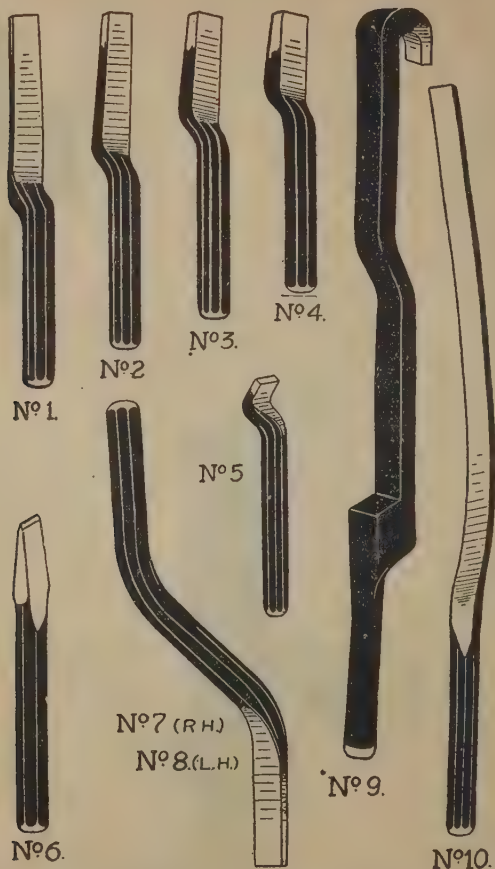
FIGS. 6,154 to 6,162.—Various caulking tools. No. **1**, yarning uron ¾ ×4; **2**, long regular iron ¾ ×3½; **3**, regular iron ¾ ×2½; **4**, finishing iron ¾; **5**, throat iron ⅝; **6**, cold chisel ¾; **7**, R. H. offset iron ¾; **8**, L. H. offset iron ¾; **9**, ceiling iron ½ ×⅝; **10**, spring yarning iron ½.
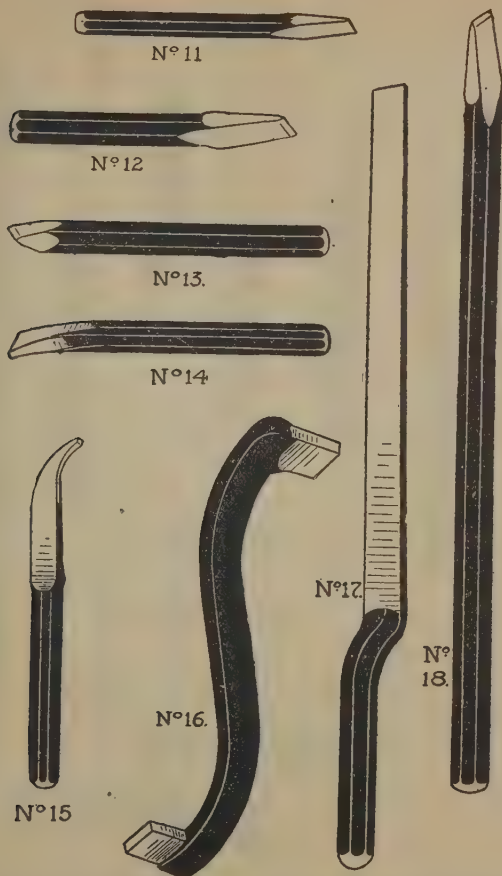
Figs. 6,163 to 6,170.—Various caulking tools. **11**, cold chisel ½ ×5½; **12**, cold chisel ¾ ×5¼; **13**, stub cold chisel ¾ ×7; **14**, stub iron ¾; **15**, picking out chisel ⅝; **16**, S-iron ⅝ ×½; **17**, long yarning iron ¾ blade; **18**, brick chisel ¾ ×18.
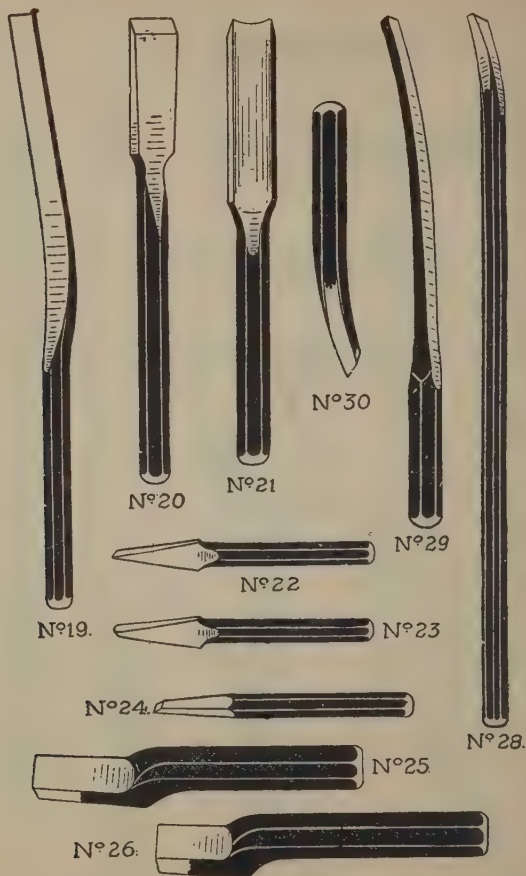
Figs. 6,171 to 6,181.—**19**, yarning iron ½ ×7; **20**, hammer head chisel 1 in. blade; **21**, hammer head gauge; **22**, cape chisel ⅝; **23**, half round cape chisel ⅝; **24**, diamond point ⅝; *1 inch caulking tools:* **25**, regular; **26**, finishing; **27**, chisel 8 in.; **28**, long bent nose iron; **29**, long curved iron; **30**, spreading and cutting tool.

The best chisels are made of selected steel with the blade almost imperceptibly widening toward the cutting edge. The blades are oil tempered and carefully tested. The ferrule and blade of the socket chisel are so carefully welded together that they practically form a single piece. The highly finished hickory handles are all of selected and thoroughly seasoned wood. Socket chisels are preferred because they are stronger and the handles are less apt to split.

In honing a chisel, use a good grade oil stone. Pour a few drops of machine oil on the stone or if no machine oil be available, use lard oil, or sperm oil. The best results are obtained by using a carborundum stone. The carborundum cuts faster than most other abrasives.

Hold the chisel in the right hand and grasp the edges of the stone with the fingers of the left hand to keep from slipping; or better, place the stone on a bench and block it so it cannot move. Both hands will thus be free to use in honing.

In this case grasp the chisel in the right hand where the shoulder joins the socket; place the middle and fore finger on the blade near the cutting edge; rub the chisel on the stone away from you, being careful to keep the original bevel.

Never sharpen the chisel on the back or flat side; this should be kept perfectly flat. For paring, the taper should be long and thin about 15°. The longer the bevel on the cutting edge, the easier the chisel will work, and the easier it is to hone it.

In sharpening a firmer chisel, it should be ground at an angle of not less than 20°, and 25° for a framing chisel. See figs. 6,149 to 6,151. In honing a chisel the taper should be carefully maintained and unless the back be kept flat it will be impossible to work to a line. Bevel edge chisels are more easily sharpened than the plain edge, as there is not so much steel to be removed.

In case the chisel be badly "nicked" it will have to be ground on a grindstone before honing. Never use a file. Be sure to use plenty of water or

the stone, so as not to injure the temper of the chisel, and be particular to keep the original taper of the bevel. After grinding, hone on an oil stone as instructed.

Brad Awls.—An awl is *a pointed tool for piercing small holes.* The blade is shaped and pointed to suit the conditions of use. Brad awls have an edge like a screw driver and can be used as such on small screws. Its principal use is in quickly making a hole for starting a nail or screw into hard wood. Figs. 6,182 to 6,184 show method of using the awl.
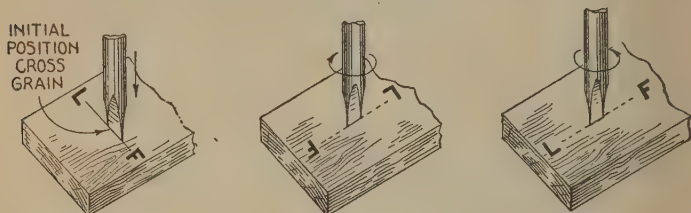
Figs. 6,182 to 6,184.—Method of using the brad awl. *Always start with the edge of the tool across the grain of the wood* as in fig. 6,182. *In forcing* the tool into the wood do not turn the tool completely around but give only sufficient turning movement in alternate directions to cut and crush the fibres, extreme positions L,F, and the arrows (figs. 6,183 and 6,184) indicating this movement.
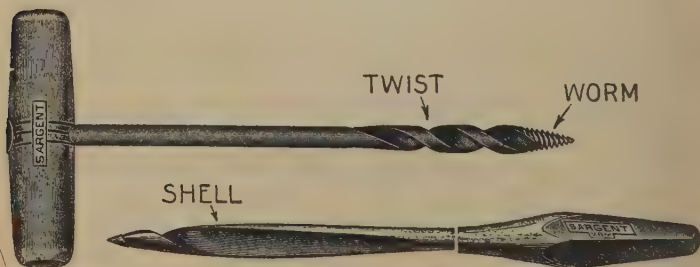
Figs. 6,185 and 6,186.—Gimlet and gimlet bit showing two constructions of the working end, *twist* (fig. 6,185) and *shell* (fig. 6,186). *In using* the gimlet, the handle is grasped in the right hand and pressed into the wood by the palm (in starting), the shaft of the tool projecting between the first and second fingers. It is driven into the wood by a series of half turns, being released and re-grasped at each half turn.

Gimlets.—These are for boring small holes by hand pressure, though the bit form of gimlet is used in a brace being adapted to heavier and quicker boring than the gimlet which has a handle. There are two kinds of gimlet: 1, twist, and 2, plain or shell as shown in figs. 6,185 and 6,186. Extra large gimlets (½ to ½ in. diam.) are called auger gimlets.
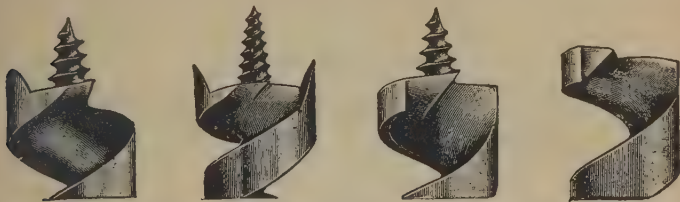
FIGS. 6,187 to 6,190.—Bit and auger heads. Fig. 6,187, single cutter, extension lip, coarse screw. Recommended for general all around boring; rapid, clean cutting and very easy boring. Particularly adapted for difficult boring in wet, green, very hard or knotty wood and boring with the grain. Fig. 6,188, double cutter, extension lip, fine screw. Recommended for furniture and cabinet work, or wherever a particularly smooth hole is essential; bores easily and clears readily. Fig. 6,189, ship head with single cutter and coarse screw. Note absence of lip. Recommended for deep boring or in woods with strong grain. Especially adapted for boring plug holes in making riveted copper fastened joints in fine boat construction. Will stand many sharpenings; does not bore as smooth a hole as types with spur.
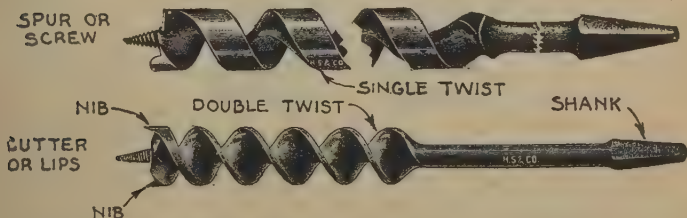
FIGS. 6,191 and 6,192.—Single and double twist auger bits. *In operation,* the screw on the end of the bit draws the tool into the wood, making a heavy pressure unnecessary. The nibs make an incision on the wood below the cut made by the cutters which take the shavings out and into the twist, this in turn lifting them out of the hole. In the single twist auger the cuttings are thrown into the center of the hole and delivered more easily than with the double twist auger, which crowds the cuttings to the walls of the hole where they are likely to become jammed between the tool and the work. The single twist type is thus adapted to boring deep holes.

A gimlet serves many purposes when a brace and bit are not at hand or when only one hole is to be bored, saving the time of setting bit in driver.

Augers.—These are used for boring holes from ½ up to two inches. The sizes are listed in 16ths, thus a 2 inch auger is listed 32. When made with a shank for use in a brace, this style of auger is commonly called a bit.
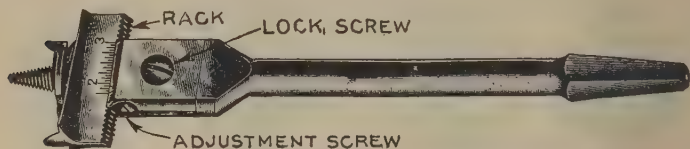
FIG. 6,193.—Wright expansive auger bit with screw adjustment and cap binder. Before the plate binds firmly, the position of extension may be adjusted by the adjustment screw on the side, to its exact position and then the plate firmly locked by the lock screw. It is seen that they can bore up to a three inch hole. Shorter extensions come separately for boring smaller holes larger than 1 in.

FIGS. 6,194 and 6,195.—Single and double thread. *The single thread* (fig. 6,194) is coarse pitch for quick boring. Especially adapted for hard or gummy woods, and grain borings mortising doors, etc. *The double thread* (fig. 6,195) is unsurpassed for accurate work in seasoned wood not extremely gummy or hard and is preferred by cabinet makers. A bit with double thread can be used for practically all work but it bores more slowly than the coarse single thread bit.

NOTE.—If finish be looked for around the point the double thread will have a lead to each lip and has some advantages as a starting cut. The single thread has the advantage of an extra amount of wood that would be taken with the other lead, say a fine screw of 28 threads on point per inch with a lead of 14, would bore one inch with 14 turns. But, to take into consideration all kinds of wood on regular work 16 per inch is good: but for fast, rough work, six or eight turns single is used with good results.—*The James Swan Co.*

How to Sharpen Augers.—To sharpen the spur, hold the bit in the left hand with the twist resting on the edge of the bench. Turn the bit around until the spur to be sharpened comes uppermost. File side spur, next to screw, carefully keeping the original bevel. File lightly until a fine burr shows upon the outside, which carefully remove by a slight brush with a file; result, a fine cutting edge.
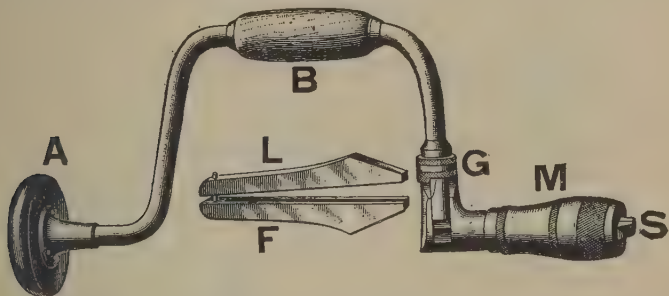
FIGS. 6,196 and 6,197.—Ratchet brace for holding bit. The jaws L,F, are held in the screw sleeve M, by means of which they are adjusted. The ends of the jaws which hold the bit are seen projecting from the sleeve at S. A, is a cap which turns loosely on the end of the brace, The auger is guided by holding the cap in the left hand, and turned by revolving the brace with handle B. The ring G, adjusts the ratchet for right or left release.

FIG. 6,198.—Goodell-Pratt angular brace for boring in close places. The brace can be fastened at any desired angle, the setting mechanism preventing slipping.

To sharpen the cutter, hold bit firmly in left hand with the worn point down on edge of bench, slanted away from the hand with which you file and file from inside back, and be also careful to preserve original bevel and take off the burr or rough edge.

Never sharpen outside of spur.

It is rarely necessary or advisable to sharpen the worm, however, it may often be improved if battered by using a three-cornered file, carefully manipulated, using one of a size that fits the thread. A half round file is best for the lip and with careful handling may be used for the spur

Twist Drills.—These are for drilling small holes where the ordinary auger or gimlet would probably split the wood.

SQUARE TAPER SHANK .

NO SCREW

STRAIGHT SHANK   TWIST
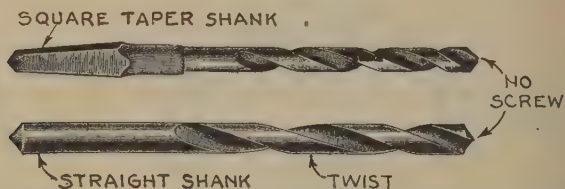
FIGS. 6,199 and 6,200.—Bit stock twist drill for use with brace and straight shank twist drill for use in breast drill chuck. Note absence of screw on cutting end which prevents splitting of the wood.
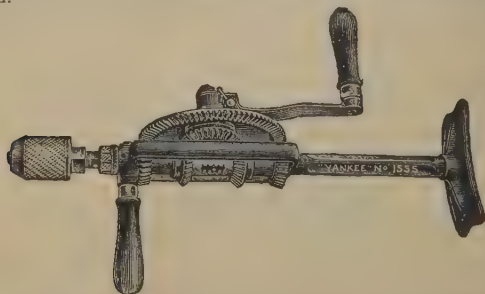
FIG. 6,201.—"Yankee" double speed breast drill with three jaw chuck holding up to ½ in. straight shank drills. It has two speeds, right and left ratchets and continuous ratchet; also direct drive.

They come either with square shanks for breast dull shocks or with round shanks for use with a brace as shown in figs. 6,199 and 6,208. These drills come in sizes from $1/16$ to $5/8$ or more varying by 32nds.

A drill differs from an auger or gimlet in the absence of a screw and a less acute cutting angle of the lip, hence there is no tendency to split the wood, that is, the tool does not pull itself in by a taper screw but enters by external pressure.
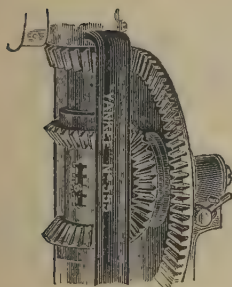
Fig. 6,202.—"Yankee" drive gear of double speed breast drill. The peculiar feature of this gear is in the shifter on cylinder between the small gears. The movement of this shifter in the various notches causes the tool to perform different movements. *In the first notch* nearest the chuck it is an ordinary or plain breast drill. *In the second notch* it becomes a left hand ratchet, useful in removing taps, but especially to loosen drill if it become jammed in a hole and cannot be removed forward or crank revolved backward. *In the third notch* it becomes a right hand ratchet. *In the fourth notch* any movement of the crank, however short, or turned continuously in either direction, or a combination of the two, the drill in the chuck will always turn to the right and drill continuously, hence no time is lost and double the work is done as compared with single or a right hand ratchet. It is especially convenient in corners, etc., where crank cannot be turned.
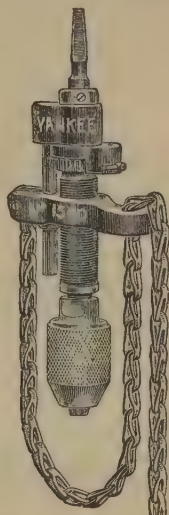
Fig. 6,203.—"Yankee" chain drill with automatic and ratchet feed. The taking up and releasing of chain is done with a friction feed, by simply turning brace or breast drill by which chain drill is operated. When the chain is tight, the automatic feed operates by turning of small lever to horizontal position as in illustration. When drill has reached desired depth the automatic feed is thrown off by turning lever to upright position. Reverse movement of brace and drill is withdrawn, chain slackened in moment. The automatic feed is positive, fixed and without adjustment for drills up to ½ inch, so that drills cannot be broken in use. There is no hand feed, nor any parts requiring attention, and nothing to catch or pinch the fingers in use.

For many operations especially where the smaller drills are used, as in drilling nail holes through boat ribs and planking, a geared breast drill is preferable to a brace.

Countersink.—This consists of a conical rose bit or fluted reamer generally used for enlarging bolt holes to a conical
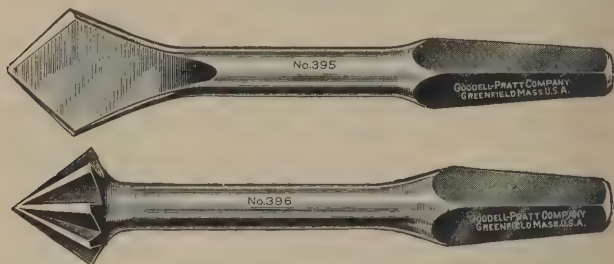
FIGS. 6,204 and 6,205.—Goodell-Pratt counter sinks. Fig. 6,204, flat, or two cutter; fig. 6,205, fluted or multi-cutter, sometimes called "Rose."
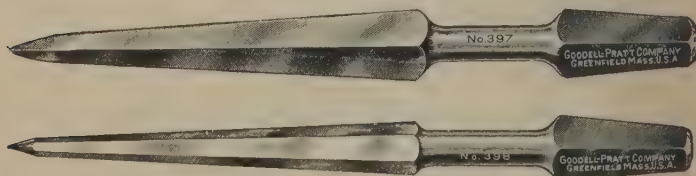
FIGS. 6,206 and 6,207.—Goodell-Pratt reamers. Fig. 6,206, square type; fig. 6,207, octagonal type.

recess for the reception of the tapered head of the bolt, which is thus let into the material so that the bolt head is flush with the exterior surface.

Reamers.—A reamer is a long tapered cutting tool for enlarging holes. While used chiefly by machinists there are frequent occasions in carpentry when a reamer may be employed

to advantage, as for instance, enlarging holes in hinges when too small for the screws on hand, etc., Fig. 6,206 shows a desirable type of reamer with square shank for use with brace.
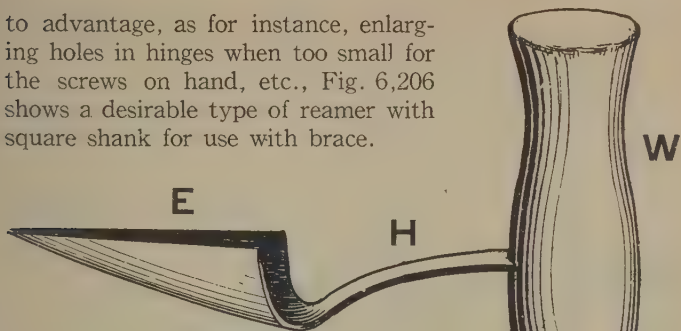
FIG. 6,208.—Tap borer. It consists of a short conical bit **E**, sharp on both edges, connected by shank **H**, to the handle **W**. Holes may be made and opened out in lead pipes or sheets by the conical bit **E**.

Tap Borer.—This is a special kind of boring instrument used by plumbers for making or enlarging holes in lead pipes, as shown in fig. 6,209.

TAPPING LEAD PIPE
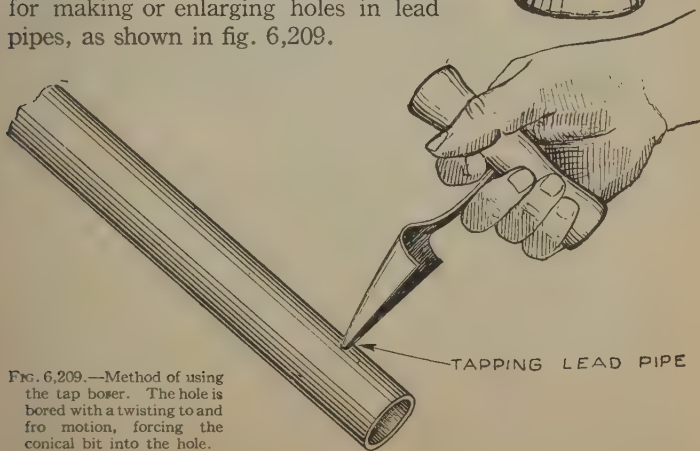
FIG. 6,209.—Method of using the tap borer. The hole is bored with a twisting to and fro motion, forcing the conical bit into the hole.

Pipe Threading Dies.—The greatest difficulty experienced in threading pipe is due to the use of dies which are inadequate to properly perform the work expected of them.

In order to obtain good results in threading any metal, the die must be made to *cut*—not *push*. A die which pushes the metal off instead of cutting it freely, causes the threads to break out of the die.

The manufacturers are not altogether to blame for improper designs, as they are forced to shape their dies so that they may best resist the abuse they receive by improper usage.
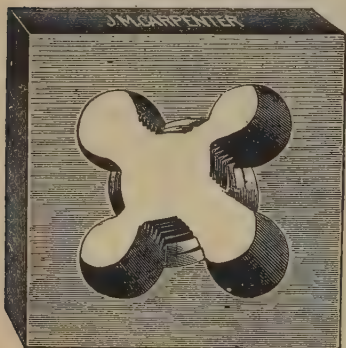
FIGS. 6,210 and 6,211.—Two forms of square non-adjustable pipe die. Fig. 6,210, solid; fig 6,211, sectional.

To insure a good thread it is necessary that dies be made with a proper consideration for: lip, chip space, clearance, lead or throat, sufficient number of dies.

Number of Chasers.—To get good results at one cut experience shows that a die should have a suitable number of chasers, the approximate number being determined by the size of the die. The experience of the National Tube Company in threading "National" pipe on power machines shows that dies up to $1\frac{1}{2}$ inches should have four chasers.

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*NOTE.—All these points are taken up at length in the National Tube Co. bulletin No. 6 D on "Correct Pipe Threading Principles," and it will repay any one interested in the subject to obtain a copy of same.

1½ in. to 4 in. should have approximately 6 chasers.
4½ " " 8 " " " " 8 "
9 " " 12 " " " " 12 "
13 " " 16 " " " " 14 "
17 " " 20 " " " " 16 "

Pipe Stock.—The pipe dies as just described are placed in a frame work called a stock, which is provided with two hand

FIGS. 6,212 to 6,217.—Walworth plain pipe stock (*without leader screw*) solid die and bushing.

FIGS. 6,218 to 6,220.—Walworth plain pipe stock (*with leader screw*) solid die and bushings.

bars for turning as shown in fig. 6,212. The stock has various size collars to fit the different sized pipes as shown in figs. 6,213 and 6,217.

Pipe Vise.—By definition a pipe vise is a gripping appliance
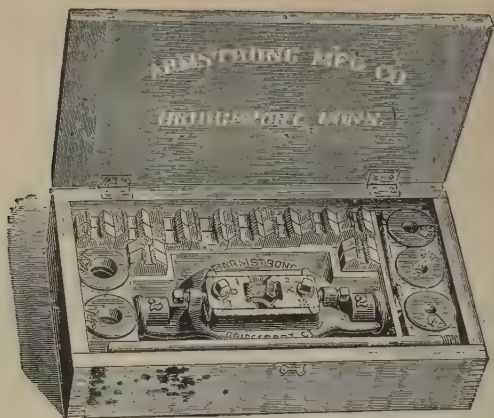
FIG. 6,221.—Armstrong *adjustable* pipe stock and dies for **single** ended dies. The dies are interchangeable in the stocks, and, although adjustable, do not need adjusting to cut the standard size for which the dies are made. The adjusting is only done when the irregularity or variations in the fitting make it necessary. There are corresponding marks $\left(\begin{smallmatrix} s \\ i \end{smallmatrix}\right)$ on the stock and on the dies $\left(\begin{smallmatrix} i \\ s \end{smallmatrix}\right)$ and when these marks are brought into lines the dies will cut the standard size. The No. 2 set shown above can, by purchasing extra dies and bushings, be used also to thread bolts and brass tubing or fine thread dies.
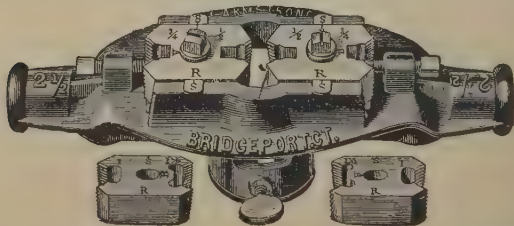
FIGS. 6,222 to 6,224.—Armstrong *adjustable* pipe stock and dies for **double** ended dies. Each pair of dies, as shown, have one size thread at one end and another size at the other. Thus the two dies in the stock are in position for cutting ½-inch thread and by reversing them they will cut ¾-inch thread. The cut shows plainly the reference marks which must register with each other in adjusting the dies by means of the end set screws to standard size.

RELEASING LEVER TO THE LEFT. OPENS THE DIES

THIS PAWL LOCKS THE LEVER

ONE OF THE THREE GUIDES

OPENING FOR THE GUIDE

OIL HOLE FOR OILING DIES

RELEASING LEVER

ADJUSTING LEVER HEEL OF DIE ACTS AS A STOP

TURN HANDLE TO OPEN OR CLOSE THE GUIDES
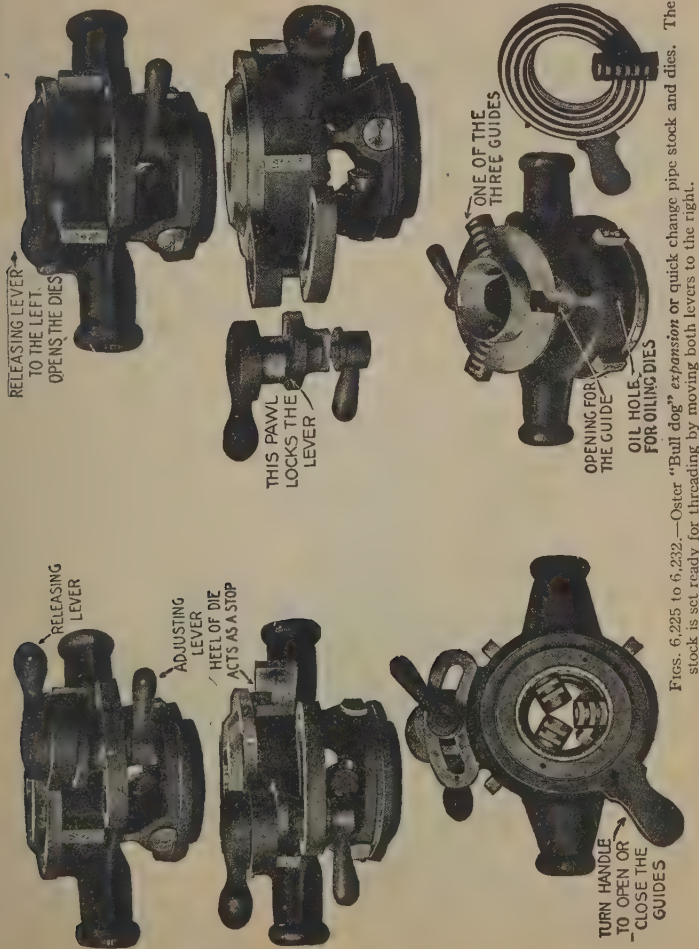
FIGS. 6,225 to 6,232.—Oster "Bull dog" *expansion* or quick change pipe stock and dies. The stock is set ready for threading by moving both levers to the right.

for holding pipes while being threaded or cut, having two V-shaped serrated jaws sliding within one another, the grip being applied or released by means of a screw and toggle as shown in fig. 6,237.
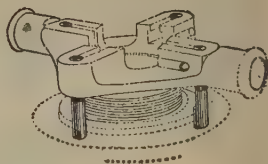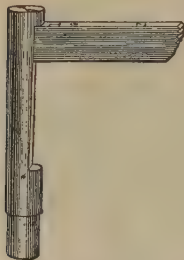
FIGS. 6,233 and 6,234.—Detail of Toledo *receding* pipe threader; *tapered pin* form. **In operation** the dies are slipped into their respective slots and pushed back until they rest against the flat tapered surface of the posts. Fig. 6,233 shows one of these posts or "taper pins," and a die resting against it in proper position in the beginning of the operation of cutting a thread. During the cutting operation the die works down on these taper pins allowing the cutting teeth to recede, thus producing the tapered thread. Shallow or deep threads may be cut by varying the position of the die on the taper pins.
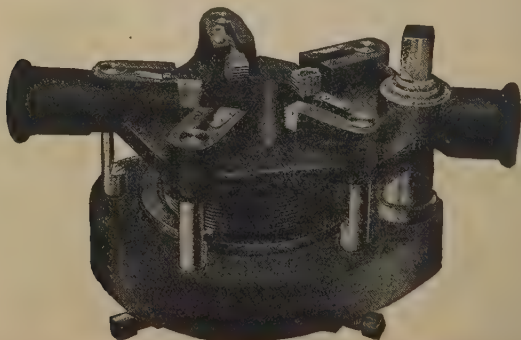
FIG. 6,235.—Toledo geared *receding* pipe threader, *tapered pin* form; capacity 2½ to 4 inch pipes inclusive. When the gear is used, a 4-inch pipe may be threaded (in 10 minutes as claimed) without undue effort.
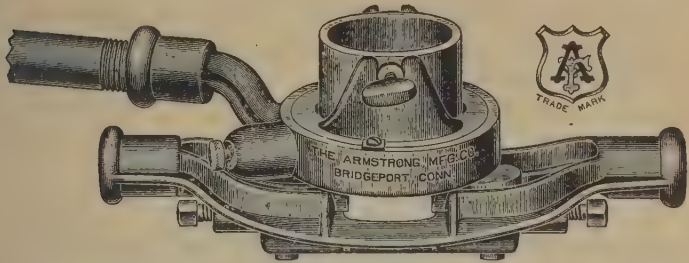
Fig. 6,236.—Armstrong ratchet attachment for stock. Can be used for either right or left hand threads by reversing pawl without removing from stock. To ratchet the die off the pipe, make one or two turns back, when the pawl can be disengaged by lifting and making one quarter turn of pawl; then turn the stock and ratchet remains idle.
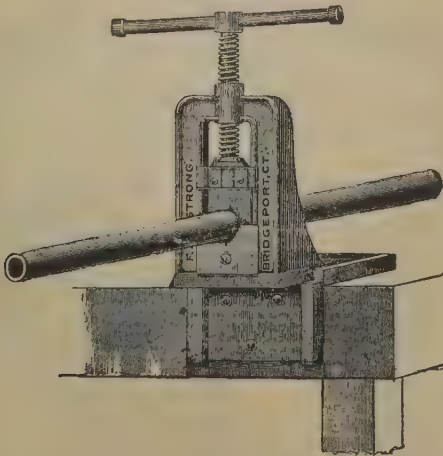
Fig. 6,237.—Ordinary pipe vise. *It consists of* a plain (as shown) or hinged U-shape piece containing the clamp screw, the sides of which form guides for the upper jaws. The upper and lower jaws are provided with a series of rectangular teeth as shown. When the U piece is closed over the pipe, pin inserted, the teeth of both jaws are brought in firm contact with the pipe by screwing down the upper jaw, thus holding the pipe firmly.

Pipe Threading Machines.—For shop work where great quantities of pipe are threaded and especially for large work, machines are necessary. These may be either hand or power operated. They are constructed with a view of saving time and labor. Of course, with the hand machine, the time consumed

Fig. 6,238.—Saunders combination die stock with loose dies. For small jobs away from the shop, this combination is well adapted, as no changes are necessary, hence no pieces to get detached and misplaced. The dies are retained by the plate and can be removed and left hand dies inserted instead, or new ones when worn.
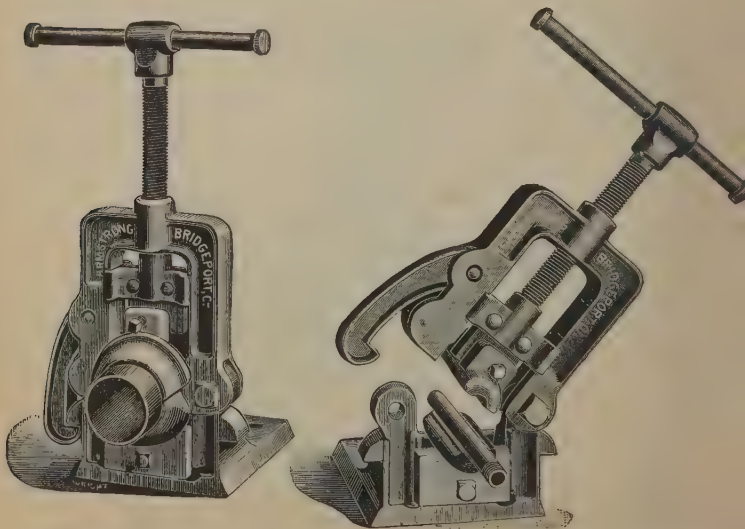
Figs. 6,239 and 6,240.—Pipe vise fitted with jaws for brass pipe. These jaws do not have teeth but hold the pipe firmly by frictional grip.

in threading pipe depends upon the activity and experience of the man turning the crank.

As usually constructed, they are so arranged that when
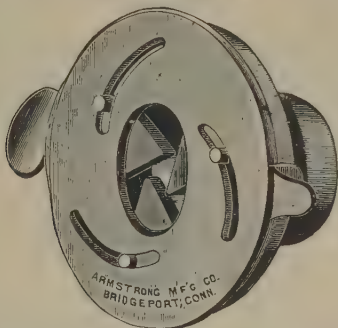
Fig. 6,241.—Bard adjustable bushing. *In operation* the jaws are moved to and from center by means of a cam plate; by fastening the plate with the thumb screw, the jaws are held firmly in any desired position. The adjustable jaws make a perfect center for the pipe, fit closely around the pipe and insure the cutting of a straight thread. When necessary a crooked or drunken thread can be cut with this bushing as easily as with a ring bushing. When once attached to the die stock, the bushing can always remain there. It does away with the necessity of carrying a number of loose ring bushings, and saves the time now lost in hunting for and changing the bushing for each size of pipe.
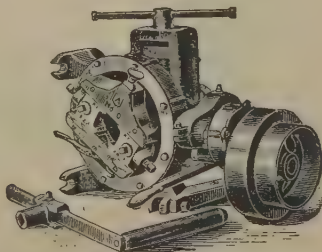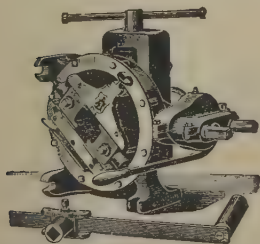
Figs. 6,242 and 6,243.—Armstrong pipe threading machine showing hand and power drive. Capacity pipe ½ to 2 inches; bolts ⅛ to 1½ inches. The dies are adjustable and are opened after cutting thread, and, after removing pipe, return to size without resetting. Two speeds are provided for hand power; the operator can cut small pipe from ¼ to 1 inch rapidly, and by changing handle to other spindle, cut 1¼ to 2 inches, not so quickly, but easily.
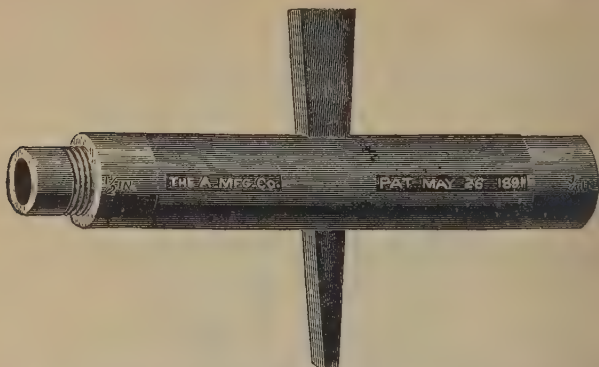
FIG. 6,244.—Armstrong nipple holder for use with hand stock and dies. As shown the holder is double ended and holds two sizes of nipples, the one illustrated being for ½ and ¾ inch nipples. *In construction,* there is a pin inside the holder having a fluted end which "digs into" the nipple end when pressed forward by driving down the wedge. *In operation* the nipple is screwed by hand into the holder as far as it will go, then the wedge is driven down sufficiently to firmly secure the nipple. The holder is so arranged that when the thread is cut, the nipple can be removed by simply starting back the wedge, which loosens the inner part of the holder and allows the nipple to be easily unscrewed by hand. The holder can be used for making either right or right and left nipples.
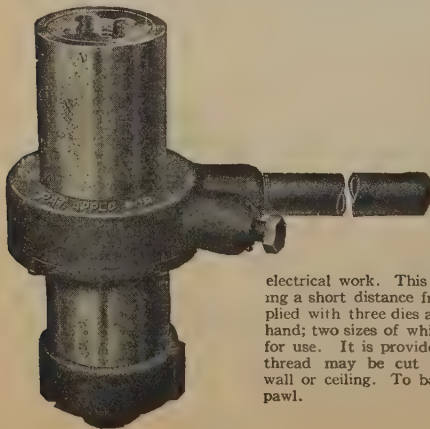
FIG. 6,245.—Armstrong ratchet ceiling nipple threader for electrical work. This tool is made to thread pipe extending a short distance from the ceiling or wall. It is supplied with three dies and bushings, ¼, ⅜ and ½ in right hand; two sizes of which are always in the holder ready for use. It is provided with a ratchet so that a close thread may be cut without marring or defacing the wall or ceiling. To back off the die, reverse the ratchet pawl.

cutting off pipe, the dies are opened for the pipe to pass through, without being removed from the machine, by a simple motion of a hand wheel or lever, and the gears and bearings are enclosed in an oil chamber, thus keeping the bearings lubricated and preventing chips or dirt getting into the working parts.*

Figs. 6,242 and 6,243 show hand and power pipe threading machines.

FIGS. 6,246 to 6,250.—Armstrong improved multi-size nipple holder and bushings.

FIGS. 6,251 and 6,252.—Pipe tap and pipe reamer.

*NOTE.—For machine cutting excellent results have been obtained with Tonowana top cutting oil.

Nipple Holder.—This is a device or sort of chuck to receive the end of a nipple which is first threaded, to save the thread from damage while the other end is being screwed.

A very excellent form of nipple holder is shown in fig. 6,246.

Pipe Tap.—By definition a pipe tap is a conical screw made
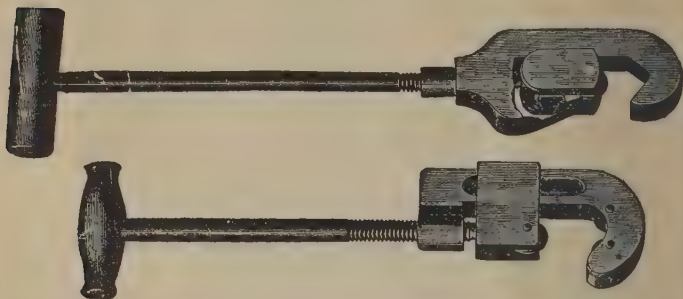
FIGS. 6,253 and 6,254.—Various pipe cutters. Fig, 6,253, one wheel cutter; fig. 6,254, Barnes three wheel cutter.

FIG. 6,255.—Saunders one wheel and roller pipe cutter.

FIG. 6,256.—Saunders three wheel pipe cutter.
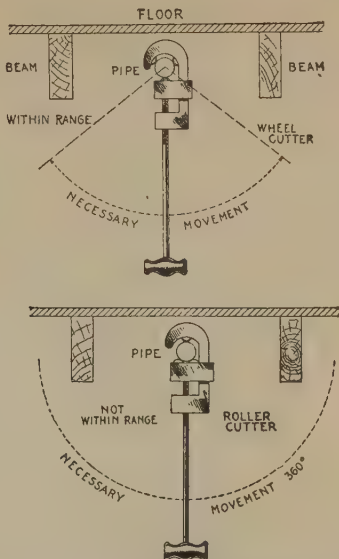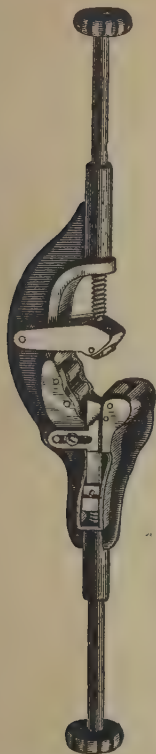
FIGS. 6,257 and 6,258.—Three wheel cutter and combined wheel and roller cutters illustrating *range*. The cuts show the comparative movements necessary with the two types of cutter to perform their functions. The three wheel cutter requiring only a small arc of movement, will cut a pipe in an inaccessible place as shown, which with a roller cutter would be impossible. Accordingly, the wheel cutter is said to have a greater *range* than the roller cutter and is therefore to be preferred for general work.

FIG. 6,259.—Saunders tool cutter for cutting brass, copper and iron tubes for boilers, etc. *In construction,* it has two handles, one to operate the tool, and the other the central swinging roller. The stock is open on the side to admit the pipe, and is provided with friction rollers, which encircle the pipe, thereby producing a rolling instead of a sliding motion, and lessening the friction on the pipe. The central roller in the swinging block is constructed with a small V near the end, which when pressed on the pipe, indents it, and by turning it around forms a small groove in the pipe, thus preventing the whole cutter moving endwise, one of the troubles usually experienced with this class of tools. In operation, its action is similar to that of a lathe tool cutting chips out and leaving the end of the pipe square and true without any burring inside or outside.

of hardened steel, and grooved longitudinally, for cutting threads in nuts, and the like.

An example of pipe tap is shown in fig. 6,251.

Pipe Cutters.—A pipe cutter is an instrument for cutting pipes as shown in figs. 6,253 to 6,259, consisting of a bent lever, partially encircling the pipe, on which one or more cutting discs are mounted, the pressure and feed of the cutting discs being regulated by a screw as the lever is rotated around the pipe.
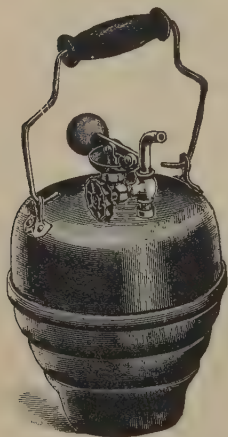
Fig. 6,260.—Plumber's thawing steamer for thawing pipes. This steamer is usually made to carry sufficient water to make steam for about two hours' continual use.

Fig. 6,261.—Force cup or so-called plumber's friend. *It consists of* a wooden handle to which is attached a large cup made of soft rubber. Used for removing obstructions from pipes.
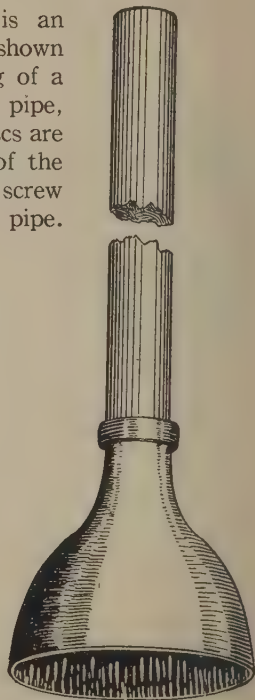
Pipe Reamer.—In cutting pipe with pipe cutters a burr is left on the inside of the pipe and this is removed by means of a reamer as shown in fig. 6,252 in order that the circulation of water flowing through the pipe may not be impeded.

The reamer consists of a fluted and tapered tool, the blades being worked out of the solid metal by planing or milling on
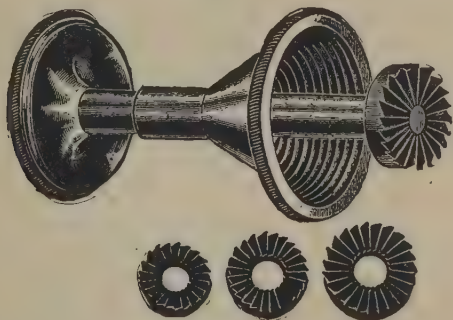
Figs. 6,262 to 6,265.—Bernz bibb seat dresser and cutters, regular style with cone threaded on the inside only.
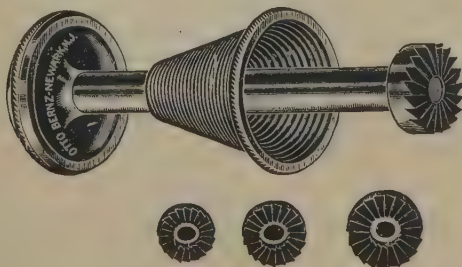
Figs. 6,266 to 6,269 —Bernz bibb seat dresser and cutters, double threaded style with cone threaded on inside and outside.

a machine. The flutes are then backed off like a tap to give a good cutting edge.

There are two kinds of reamers. Tapping reamer to ream out the pipe
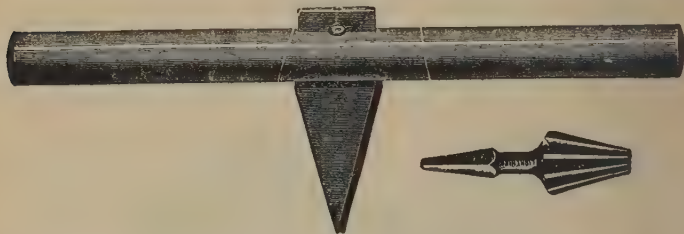
FIGS. 6,270 and 6,271.—Various burring reamers for removing burrs from pipe ends after cutting. Fig. 6,270, Hall patent reamer; fig. 6,271, reamer for use with brace.
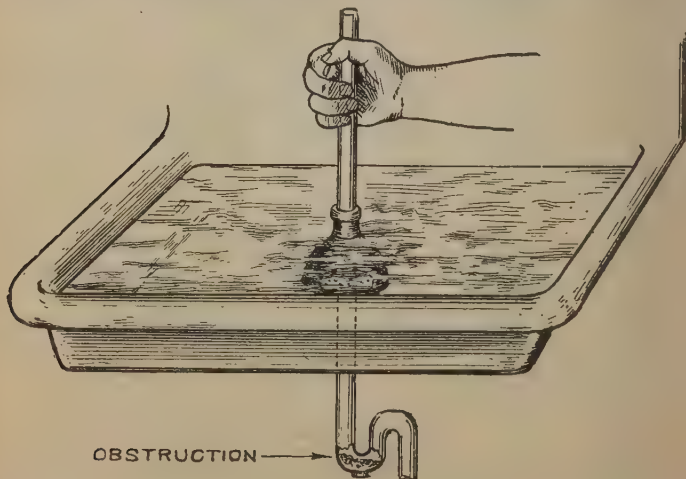
OBSTRUCTION

FIG. 6,272.—Application of force cup to clogged outlets of sink. By placing the cup over the outlet and giving it several sharp strokes downward, the disturbance of the water in the pipe will in ordinary cases dislodge the obstruction.

to the right size for Briggs standard pipe taps, as shown in fig. 6,252, and the burring reamer for removing burrs caused in pipe cutting as mentioned above. Two forms of burring reamer are shown in figs. 6,270 and 6,271.

Pipe Bending Tools.—There is quite a variety of devices
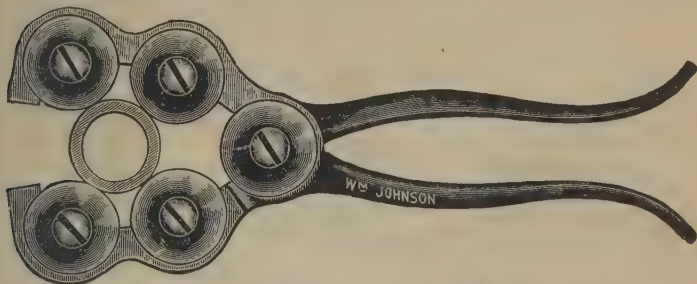
FIG. 6,273.—Five wheel lead pipe cutter.

FIG. 6,274.—Lead pipe expanding pliers.
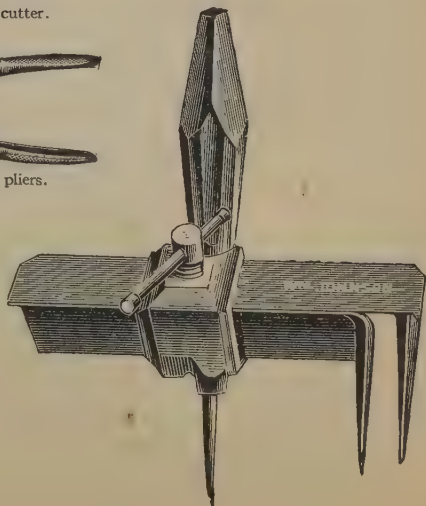
FIG. 6,275.—Washer cutter.

composing hand tools and machines for bending pipe. Fig. 6,276 shows the smallest and simplest device which is intended to be bolted to a table and is suitable for bending pipe of small sizes ranging from ½ to 2 ins. Fig. 6,277 shows a pipe vise
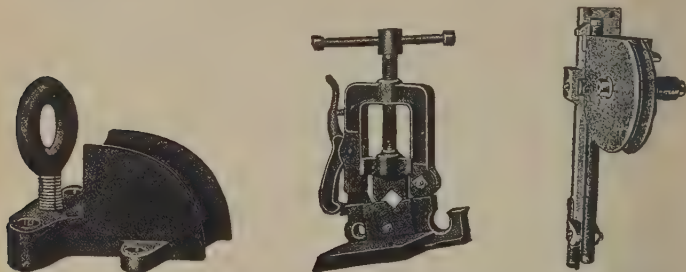
FIGS. 6,276 to 6,278.—Pipe bending devices. Fig. 6,276, Vanderman bending form; fig. 6,277. Vanderman pipe vise with bending form combined; fig. 6,278, small pipe bending machine, suitable for ¾ to 1¼ in. pipe.
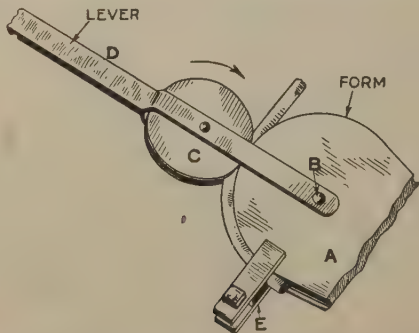
FIG. 6,279.—Common bending device consisting of a circular form **A**, with bending pulley **C**, radially hinged at **B**. Owing to the considerable effort required to bend pipe, the part **A**. must be very securely fastened to some rigid support. *In bending* the lever is brought over to the projection **E**, and pipe placed in position. Then the lever is forced around in the direction indicated by the arrow, thus bending the pipe to conform with the bending form. The pipe, of course, must first be filled with sand and capped to prevent buckling, and also heated if the bending radius be small enough to require heating.

with bending forms combined, and fig. 6,278 a machine suit-
able for pipes ¾ to 1¼ ins.

A common tool for bending to circular form is shown in
fig. 6,279. For bending small pipe under one inch in size, a
bending tool known as a hickey can be made out of a length
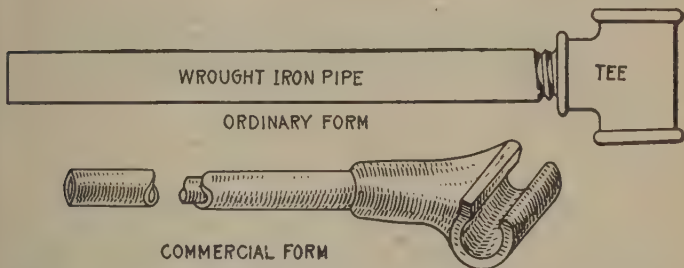
FIG. 6,280.—Ordinary form of hickey or conduit bender. *It consists of* a piece of one inch
wrought pipe about three feet long with a one-inch cast iron tee screwed ont one end of the
pipe. This device is used as follows: the conduit to be bent is placed on the floor and the
tee slipped over it. The workman then places one foot on the conduit close to the tee, and
pulls the handle of the bender towards him. As the bending progresses, the workman should
take care to continually move the bender away from himself, to prevent the buckling of
the conduit.

FIG. 6,281.—Commercial form of hickey or conduit bender

FIG. 6,282.—Machine for making quarter bends. This type of a tool should be used on large
jobs where a number of bends the same size is desired.

of pipe and a T fitting as shown in fig. 6,280. A more desirable form of hickey is shown in fig. 6,281.

Hammers.—The hammer is an important tool in any line

FIG. 6,283.—Stanley bell face, octagonal neck and poll, nickel plated mahoganized handle nail hammer.
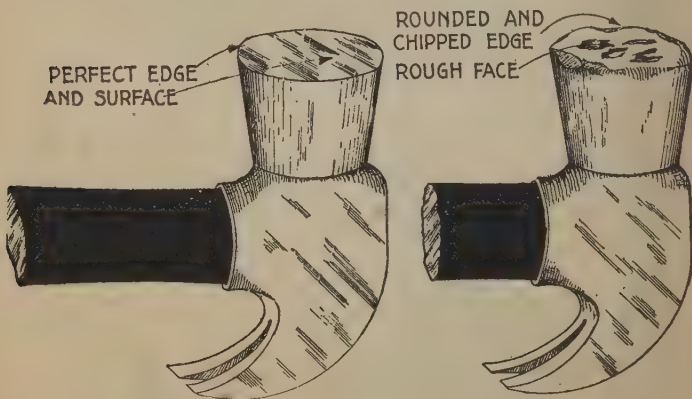
FIGS. 6,284 and 6,285.—Appearance of a good and a poor hammer after use.

of mechanical work and there are numerous types to meet the varied conditions of use. All hammers worthy of the name are made of best steel carefully forged, hardened and tempered.

Don't expect to get a good hammer in the five and ten cent store; buy only the best.
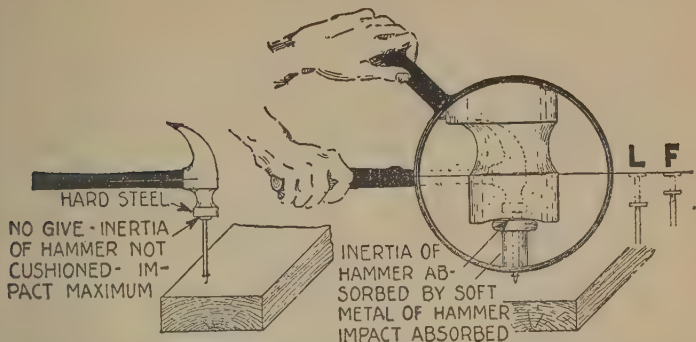
FIGS. 6,286 to 6,289.—Why a cheap hammer should not be used. The force that drives the nail is due to the *inertia* of the hammer, and this depends upon the suddenness with which its motion is brought to rest on striking the nail. With hardened steel there is practically no give and all the energy possessed by the hammer is transferred to the nail. With soft and inferior metal all the energy is not transferred to the nail, hence the drive per blow is less as at **F**, than with hardened steel, as at **L**.

FIG. 6,290.—Wensley caulking hammer, weight 2½, 3, 3½ lbs.

FIGS. 6,291 to 6,294.—Wensley raising hammers. Various sizes, ranging from 28 to 82 ozs.
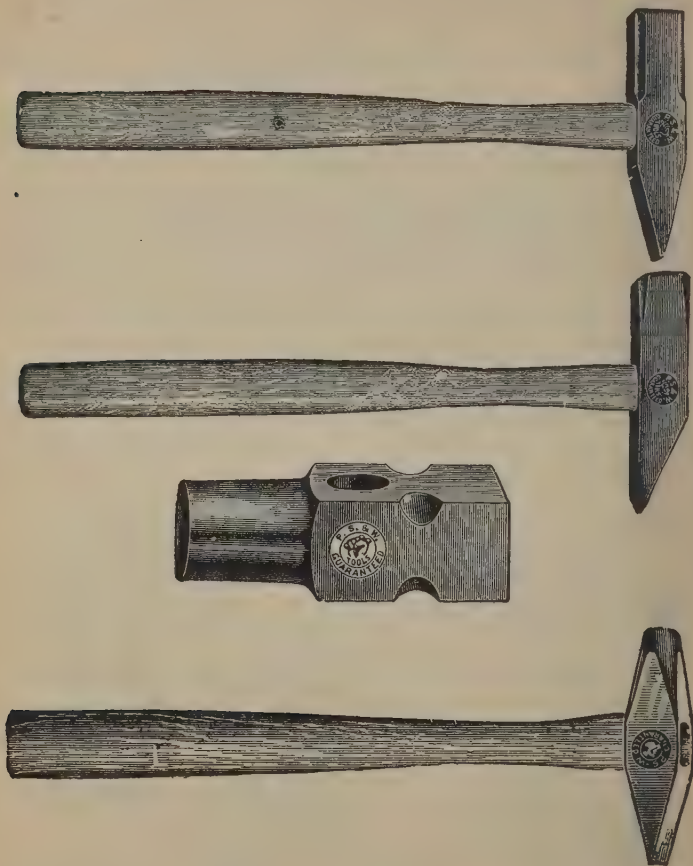
FIGS. 6,295 and 6,298.—Wensley riveting and setting hammers. These hammers are made from crucible steel, tempered and hardened. They are of correct design for sheet metal workers' use.

In this connection figs. 6,286 to 6,289 show why cheap hammers should not be used. Various hammers as for caulking, planishing, raising, riveting, setting, etc., are shown in figs. 6,290 to 6,298.

Screw Drivers.—A screw driver is very similar to a chisel and differs from the latter chiefly in the working end, which is blunt. There are very few screw drivers having a correctly
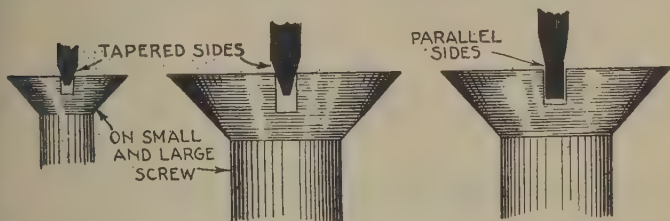
FIGS. 6,299 to 6,301.—Action of screw driver with ends having tapered and parallel sides. Figs. 6,299 and 6,300 show large range of work with tapered sides but considerable downward pressure must be exerted to prevent the screw driver rising out of the slot. Fig. 6,301 shows correct shape. Evidently with parallel sides there will be no tendency for the screw driver to rise, no matter how much turning force be exerted.

FIG. 6,302.—Small screw driver with short round blade.

FIG. 6,303.—Swan screw driver bit for use with brace.

shaped end. Usually the sides which enter the slot in the screw are tapered. This is done so that the end will fit into screws of widely varying sizes.

In using a screw driver having a tapered end a force is set up due to the taper which tends to push the end of the tool out

of the slot. Accordingly it is better to have several sizes with properly shaped parallel sides than to depend on one with tapered sides for all sizes of screws. There are two general classes of screw drivers, the *plain*, and the so-called *automatic*.

Figs. 6 304 and 6,305 show typical plain screw drivers. The operation of driving a screw with a plain screw driver consists of giving it a series of half turns.

Where a number of screws are to be tightened there is a saving in time by using a screw driver bit which is used with a brace the same as an auger

OBJECTIONABLE TAPERED END
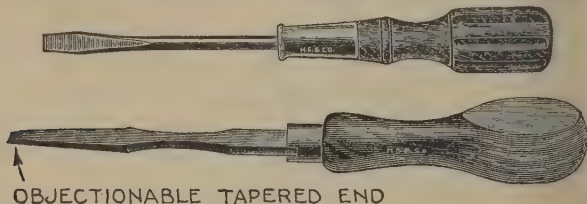
Figs. 6,304 and 6,305.—Plain screw drivers. Fig. 6,304, round pattern; fig. 6,305, flat pattern. In fig. 6,305, note the objectionable tapered sides at the ends. The reason manufacturers shape the ends this way is to adapt the tool to a large range of work, because most workmen make the mistake of false economy and buy only one screw driver, whereas they should have several different sizes with properly shaped ends as explained in the text.

Fig. 6,306.—"Yankee" ratchet screw driver, right and left hand. At the blade end there are two spring jaws fastened together as shown and kept in place by ring surrounding them, which ring is fastened to fork on end of blade. A spring between fork and lower end of jaws keeps latter in position to hold screw eye, as shown. Pushing up the jaws with thumb of hand holding driver, the point of jaws readily opens to insert screw eye, which should be pushed down into holder so it rests solidly in V-shaped groove. The jaws are then released and grasp screw eye. The ratchet works either right or left hand, for driving or taking out screws. *In operation,* the jaws are pushed over screw eye and driver turned, the spring jaws holding screw eye when loosed, so it does not fall to floor. The knurled washer on blade is to start screw eye with thumb and forefinger, while the hand holds the tool. Especially adapted to places where only one hand can be used.

bit. The quicker method of driving a screw is by means of the so called automatic screw driver shown in fig. 6,306 (there being various types). The advantage over the plain screw driver is that instead of grasping and releasing the handle from 25 to 30 times in turning a screw home, it is

grasped once and with two or three strokes back and forth the screw is driven home, thus saving labor and time.
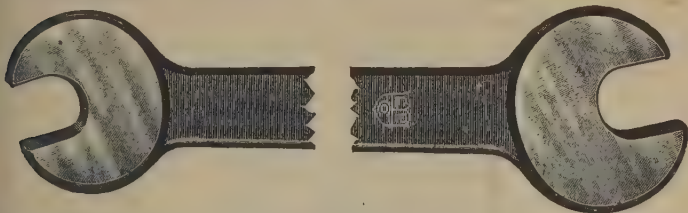
FIG. 6,307.—Goodell-Pratt double end type plain wrench. The feature of this wrench is that it will fit two sizes of nuts and the sides of the jaws being at an angle to the body of the wrench, admits of turning a hexagon nut with a smaller swing than would be possible with the straight type. This permits working in close places.
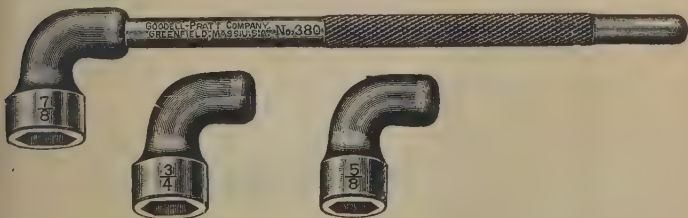
FIGS. 6,308 to 6,310.—Goodell-Pratt socket wrench and sockets. Evidently such type of wrench is adapted to working in close places and since the socket surrounds the wrench there is no danger of it slipping off the nut as in the case of the two jaw wrench.

NOTE.—Special screw drivers may be obtained with spirals of different angles to suit working conditions, Goodell Pratt's practice is: 40° spiral for rapidly driving small screws; 30° spiral for general work; 20° spiral for driving large screws in hard wood.

NOTE.—"Yankee" *push brace.* This tool is so named because it will hold all the small tools used in a bit brace, but is operated by pushing the handle to revolve the tools, in same manner as a Yankee spiral ratchet screw driver. It is adapted especially to the lighter work ordinarily done by a brace. It will, with little effort, bore 3/16 holes in metal, drive 3/8 inch auger bit in hard woods or will drill holes, drive screws in or out; can be used for tapping holes, and with socket bit drive in small lag screws, run burrs, or nuts, on bolt s, etc. The tool being straight and cylindrical and operated by pushing, can reach into many places, in corners, holes back of obstructions where a brace cannot be operated. The ratchet movements enable this push brace to be used for occasional extra heavy work than can be conveniently done by the push movement. The spiral rod is of steel, grooved for both right and left hand, with extra long (1½ in.) nuts of hard bronze, to secure extra durability. All the working parts are protected by sleeves, so no parts are exposed to dirt and grit. This push brace is especially useful in car shops, for fitting up either wood or steel cars, bridge or structural work templates, pattern makers, in garages.

Wrenches.—There has been placed on the market an undue multiplicity of wrenches of many kinds and patterns for every conceivable use. The wrench, though it may not be so considered, is a somewhat dangerous tool, when very great force
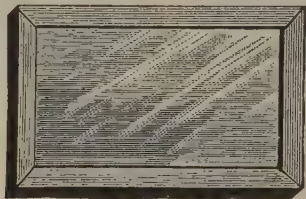
Fɪɢ. 6,311.—Plumber's looking glass. Measures 2½ ×3¾.
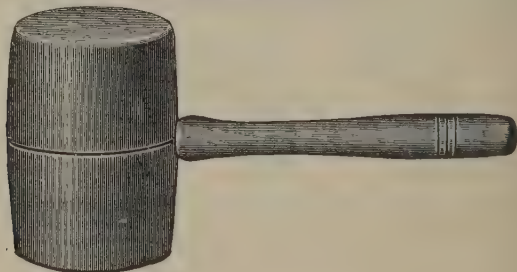
Fɪɢ. 6,312.—Mallet made from dogwood. Ordinary size 3 ×6.

is applied to start an obstinate nut. Often under such conditions the jaws slip off the nut, resulting in injury to the workman by violent contact with some metal part.

There are three general classes of wrench:

1. Plain.
2. Adjustable.
3. Socket.
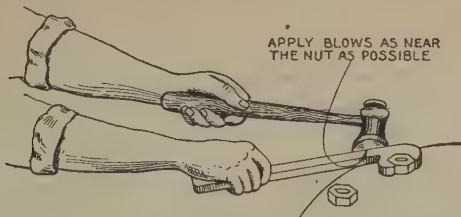
FIG. 6,313.—Starting an obstinate nut or bolt. Rusty, or large nuts or bolt heads often require more than a straight pull. A sharp blow with a hammer often starts an obstinate nut, where a straight pull would not. It is not advisable only in extreme cases to use the hammer on wrench, but a hard wood block will do as well. In extreme cases a steady pull aided with blows will do the work. *The blow should be delivered as near the nut as possible* as shown in the figure, *instead of at the other end of the wrench as is usually and erroneously done*, thus avoiding the spring and inertia of the wrench, and delivering the full energy direct to the nut.
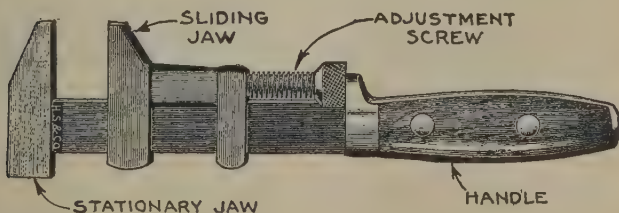
FIG. 6,314.—P, S, and W, "monkey" wrench.
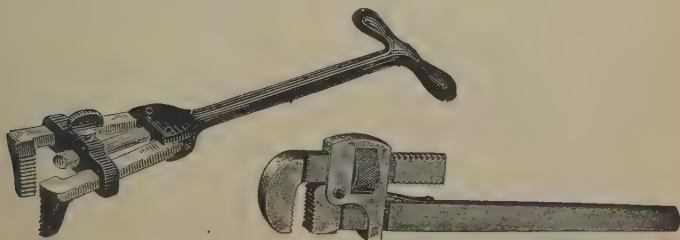
FIG. 6,315.—Basin wrench.
FIG. 6,316.—Stillson wrench.

Plain wrenches are made in a variety of patterns, the jaws being fixed with opening to suit a certain size nut. The principal adjustable wrench is the screw or so called "monkey" wrench of which everyone is familiar. The Stillson wrench as shown in fig. 6,316 for turning pipe is a variety of monkey wrench having serrated jaws to enable it to grip a pipe or round surface, thus fitting it to act as both *pipe tongs* and *spanner*.
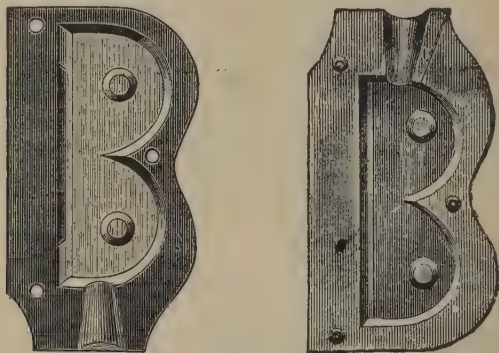
Fig. 6,317 and 6,318.—Bernz cast brass tack moulds. Plain single style.
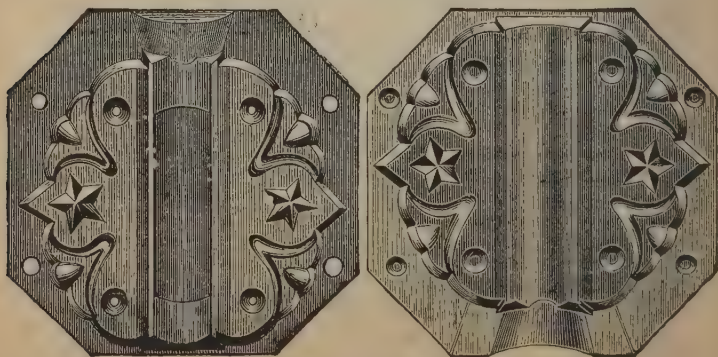
Figs. 6,319 and 6,320.—Bernz cast brass tack moulds. Fancy double style.

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a
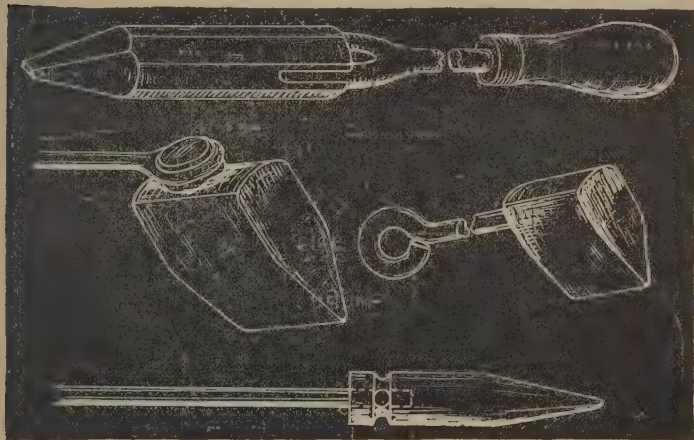
FIGS. 6,321 to 6,324.—Various soldering bits, or so-called "irons." Fig. 6,321, ordinary edge bit; figs. 6,322 and 6,323, hatchet bit; fig. 6,324, pointed bit.
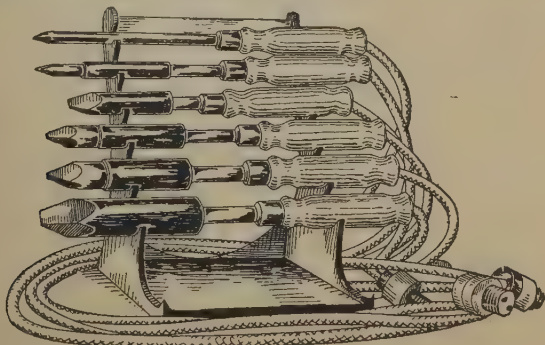
FIG. 6,325.—Nest of electric soldering bits, showing various forms and sizes.

point or edge and fastened to an iron rod having a wooden handle. The various types of bit are shown in the accompanying cuts.

Solder Pot and Ladle.—The pot as shown in fig. 6,329 is
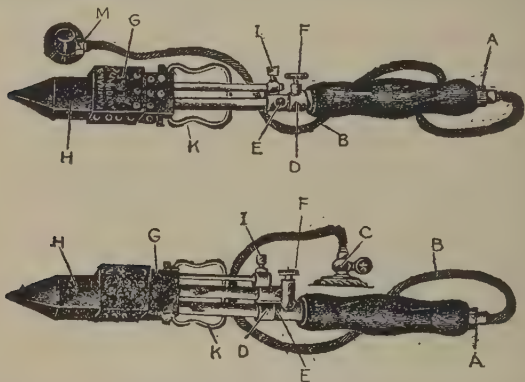
Figs. 6,326 and 6,327.—Kageman self-heating gas soldering bit for bench work. Fig. 6,326, single torch, fig. 6,327, double torch. Any shape or weight of copper point for any class of work may be easily substituted by means of a set screw I. One end of a flexible tubing is attached to the nozzle or male screw near the handle A, and the other end is connected to the gas main M. (Five-eighths main preferred.) Before lighting, close the Bunsen holes E, by means of the air slide D, open the governor F, turn on gas main M, light near copper point at G, and gently open Bunsen holes by means of slide D. If flame appear within chamber E, turn off gas, slightly close holes by means of slide D, and light again. Shut off gas at main cock M. Where the gas main is already installed it is advantageous to bore a hole in the bench near the wall, connect a flexible metallic tubing to the gas main, pass tubing through the hole and fasten tubing to the underside near the outer edge of the bench. In that way the hose will hang freely and will hardly be noticeable. The soldering iron can be used away from the bench at any desired distance, depending upon the length of the tubing. The double torch, fig. 6,327, has two burner tubes generating two short but intensely hot blasts. The double flame is intended to heat heavy coppers quickly, and when the desired temperature is reached one flame is shut off by a half turn of the governor, the remaining flame keeping the point at a steady temperature throughout the day. For smaller coppers one flame is sufficient. When a large heating power is required it is often desirable to use both blasts throughout the day.

made of cast iron and is intended for holding solder or lead which is to be melted. For ordinary jobs it should hold about 15 lbs. of melted metal.

The ladle as shown in fig. 6,328 is used for pouring solder in joint wiping, and for pouring lead in making joints in cast iron pipes. The best pattern

FIGS. 6,328 and 6,329.—Plumber's melting or solder pot and ladle for dipping out the lead or solder melted in the pot.
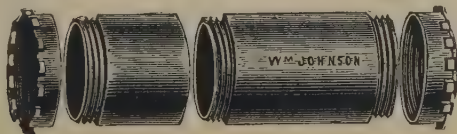
FIGS. 6,330 to 6,333.—Plumber's grease, rosin and flour box.

of ladle is provided with three lips so that the melted lead can be poured in three different directions.

Wiping Cloths.—These cloths are made out of moleskin
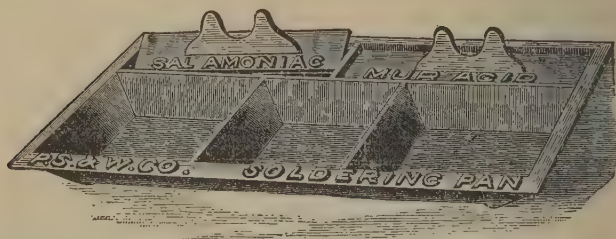
FIG. 6,334.—Cast iron soldering pan with compartments for salamonic and muriatic acids.

FIGS. 6,335 and 6,336.—Tap borers. Fig. 6,335, regular or New York pattern; fig. 6,336, Philadelphia pattern.
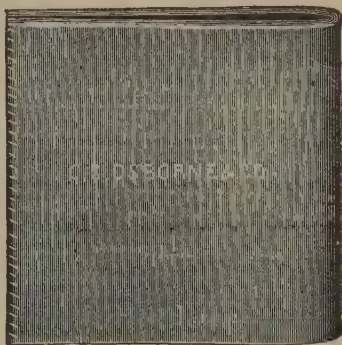
Figs. 6,337 and 6,338.—Plumbers' wiping cloths, fig. 6,337, herringbone ticking, 16 ply with stripe; fig. 6,338, moleskin.
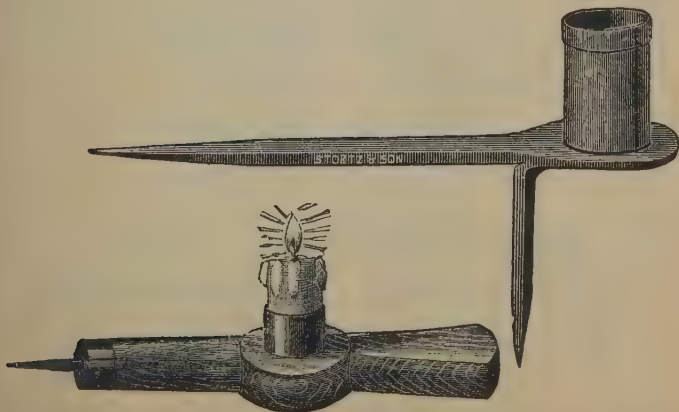
Figs. 6,339 and 6,340.—Stortz candle holders. Fig. 6,339, all metal; fig. 6,340, hard metal holder with brass ferrule on end, sharp pointed steel pin and zinc tube candle receptacle.

cloth or bed ticking. They may be purchased or made by the workman. The following are the approximate sizes used:

Wiping Cloths

Size of Pipe	Size of Cloth	Layers
$\frac{1}{2}''$, $\frac{3}{4}$	$3\frac{1}{2} \times 4$	6
$1''$	$4 \times 4\frac{1}{2}$	8
$1\frac{1}{4}''$, $1\frac{1}{2}''$	$4\frac{1}{4} \times 4\frac{1}{2}$	8
$2''$	$4\frac{1}{2} \times 5$	8
$3''$	5×6	8
$4''$	6×7	8 or 10

Torches and Fire Pots.—For small soldering jobs an ordinary gasoline torch will be found convenient. A typical torch specially adapted for heating soldering bits is shown in fig. 6,343.
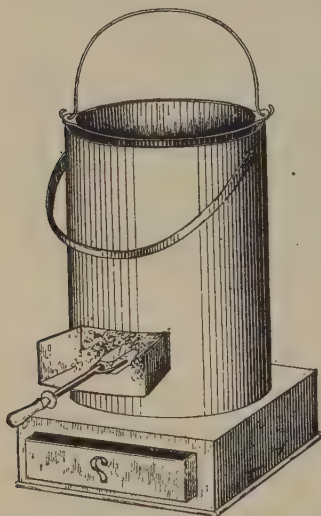
FIG. 6,341.—Plumber's ordinary charcoal fire pot, showing solder pot being heated on top and soldering iron below.
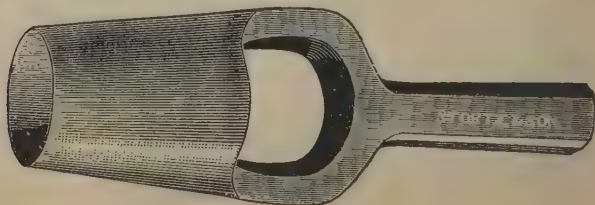
FIG. 6,342.—Stortz large round punch. Sizes for holes $\frac{7}{16}$ to 3 ins.
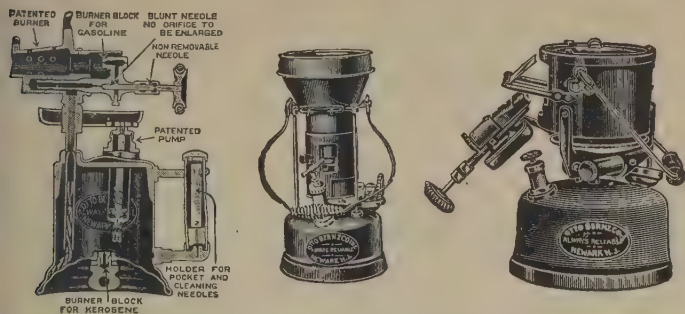
FIGS. 6,343 to 6,345.—Clayton and Lambert torch and fire pots, fig. 6,343, sectional view or torch; fig. 6,344 coil fire pot; fig. 6,345, double burner fire pot.

FIGS. 6,346 and 6,347.—Pecks slow tinners fire pots. Fig. 6,346, specially adapted for sheet metal workers. It is lined with fire brick and made in a substantial manner. The draught door is in two sections; fig. 6,347 is so constructed that the ashes fall into a pan beneath the grate and the fire is kept clear and the draught is good.

Dummy.—This tool used to straighten out kinks in pipe produced in bending and consists of a long rod, loaded on one end with a ball of coarse solder as shown in fig. 6,349. It is used as shown in fig. 6,350.
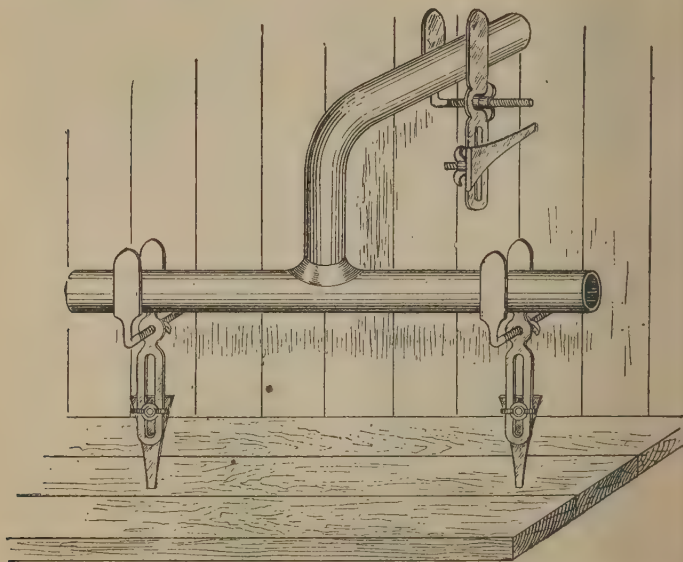
FIG. 6,348.—Starbuck adjustable pipe holders for holding lead pipe in all positions while making wiped joints.

BALL OF SOLDER

SLIGHT BEND
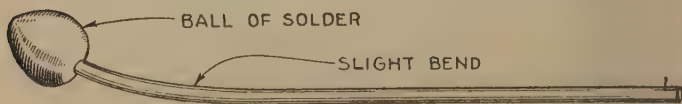
FIG. 6,349.—Dummy.

Dresser.—This is a box wood, or other hard wood tools, shaped as shown in fig. 6,352. It is used for working sheet lead and lead pipe. Iron being harder than lead, tools made of this metal mark and bruise lead, consequently wooden tools
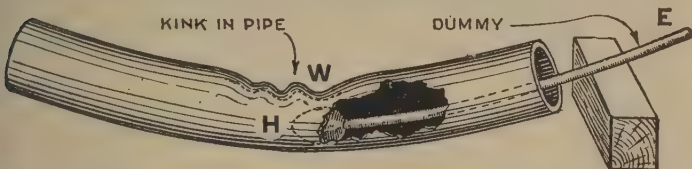
Fig. 6,350.—Application of dummy to remove kink in bent pipe. *In operation*, a sudden jerk downward on end **E**, will throw up the loaded end **H**, with great velocity, the impact driving out the kink **W**.
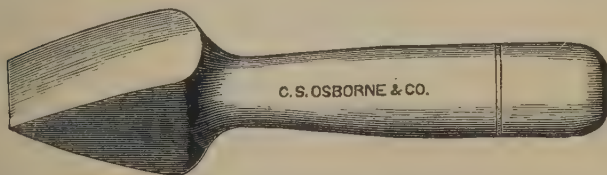
Fig. 6,351.—Plumber's side edger made of dogwood or lignumvitae.
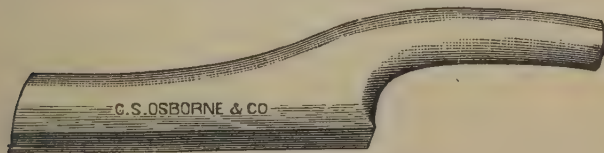
Fig. 6,352.—Plumber's dresser made of dogwood or lignumvitae.
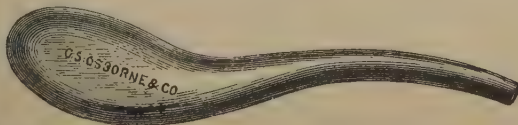
Fig. 6,353.—Bossing stick.

are used instead for hammering and treating lead into various shapes.
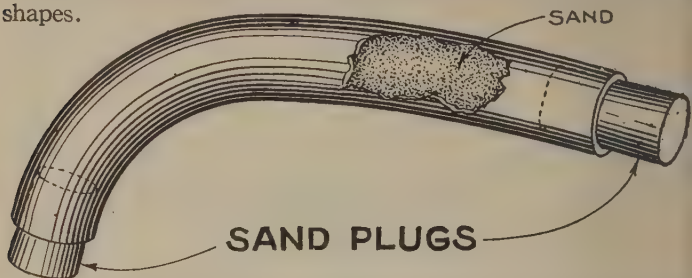
FIG. 6,354.—Application of sand plugs to ends of pipe. These plugs prevent the sand, which is packed in pipe, coming out.
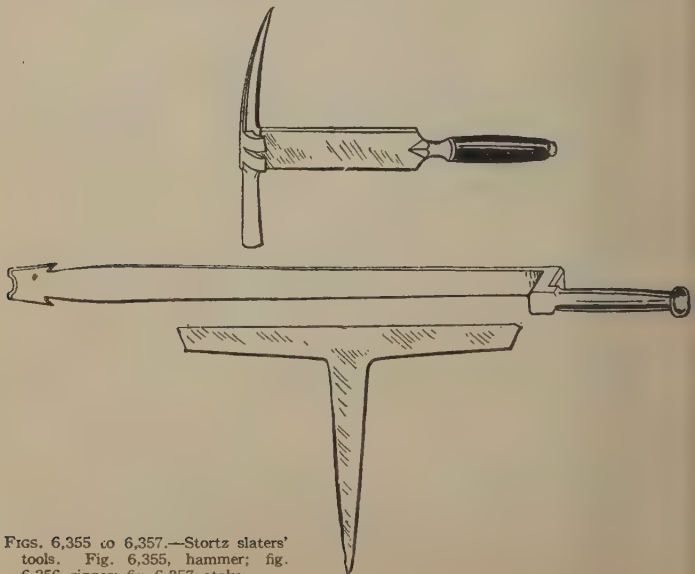
FIGS. 6,355 to 6,357.—Stortz slaters' tools. Fig. 6,355, hammer; fig. 6,356, ripper; fig. 6,357, stake.
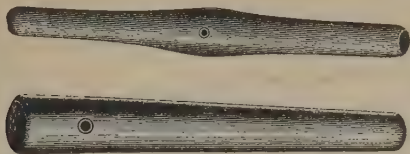
Figs. 6,358 and 6,359.—Sand plugs, fig. 6,358 No. 1 set of 8; fig. 6,359 No. 2 set of 4.
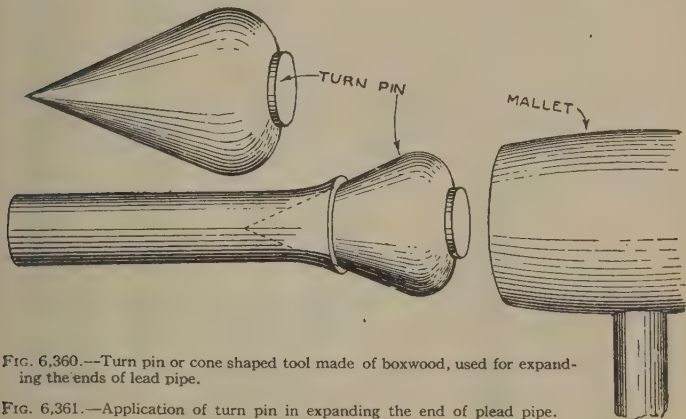
Fig. 6,360.—Turn pin or cone shaped tool made of boxwood, used for expanding the ends of lead pipe.

Fig. 6,361.—Application of turn pin in expanding the end of plead pipe.
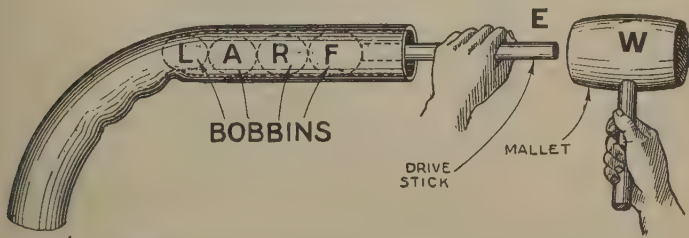
Fig. 6,362.—Application of bobbins in removing kinks formed in bending pipe. The bobbins **L,A,R,F,** progressively increasing in size, are forced through the pipe by hitting the drive stick **E,** with the mallet **W.**

Sand Plugs.—In order to prevent kinks in bending a pipe, the pipe is filled with sand and sand plugs driven in at the ends, as shown in fig. 6,358.

Bobbins.—These consist of egg shaped pieces of wood varying in sizes, which are forced through a bent pipe to remove kinks, as shown in fig. 6,360.

FIG. 6,363.—Grooving tool.

FIG. 6,364.—Tinner's roofing scraper.

FIGS. 6,365.—Roofing double seamer to match tongs.

FIGS. 6,366 to 6,368.—Stortz tinners' chisels. Fig. 6,363, circular; fig. 6,364, lantern; fig. 6,365, wire.

FIGS. 6,369 to 6,372.—Various roofing tools.   Fig. 6,369, tongs; fig. 6,370, gutter tongs; fig. 6,371, clamp tong; fig. 6,372, adjustable roofing tongs.
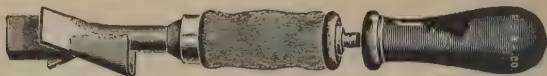
Fig. 6,373.—Rapid roofing cleater and nailer. *In operation* it folds the cleat and nails it to the sheathing. For standing lock roofs the cleat and cleater are hooked over the roofing; a quick movement to one side bends the cleat at right angles and close to the roofing and sheathing. The plunger is then raised and the nail, which has been dropped by the operator, point down into the funnel-shaped pocket on the side of the cleater, slides down against the cleat. A sharp, downward stroke of the plunger drives the nail through the cleat and into the sheathing. It is adapted to tin and sheet metal roofs of various kinds and will nail flat seam roofs rapidly and well.

CHAPTER 108

Lead Work

1. Soldering

By definition, *soldering* is the act or process of forming joints upon or between metallic surfaces, by means of a fusible alloy or solder, whose melting point is lower than that of the metals sought to be united.

Briefly the process is as follows: After careful cleansing, a *flux* is applied to prevent oxidation while heated, a suitable quantity of solder is fused on the joint, by a heated copper bit or by the blow pipe flame, according as to whether soft or hard solder is employed. The soft solder easily follows the track of the iron, along the heated parts by surface tension, but the hard solder requires more careful preparation and manipulation.

Those who have made a first attempt at soldering will agree that it is a distinct art in itself, and while it looks easy, is not; moreover, skill cannot be acquired without considerable practice; however, the information to be obtained in books will be found helpful, not only to the beginner, but also to the experienced workman.

Solder.—The word solder is a name for *any fusible alloy used to unite different metal parts.*

In electrical engineering the solder used is practically always an alloy of tin and lead. As the electrical conductivity of such an alloy is usually about one-seventh that of copper, the best joint between copper conductors is made *by bringing the copper surfaces as close together as possible and using a minimum of solder*.

There are two general classes of solder: **soft and hard.**
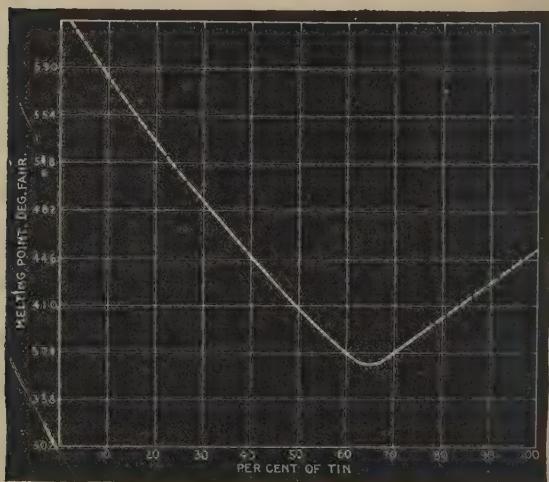
Fig. 6,374.—Characteristic curve showing the melting points of *tin lead* solders, according to the Smithsonian Institution tables. Authorities differ as to the exact values.

Soft solder is composed of lead and tin. Sometimes other metals are added to lower the melting point.

Hard solder is composed of copper and zinc, or copper, zinc, and silver. Hard solder in general is sometimes erroneously called **spelter.**

A necessary relation that must exist between solder and the metal with which it is to unite is that the solder must have a lower melting point than the metals to be joined to it.

The melting point should approach as nearly as possible that of the metals to be joined so that a more tenacious joint is obtained.

To increase the fusibility of a solder, add a small portion of bismuth.

Soft solder melts at a low temperature compared to hard solder which melts at a red heat.

Soft Solders.—These consist *chiefly of tin and lead*, although other metals are occasionally added to lower the melting point.

Those containing the most lead are the cheapest and have the highest melting point. According to the tin content they may be classed as 1, common or plumber's; 2, medium or fine.

Melting Points and Hardness of Tin Lead Solders

Percentage		Melting Temp. Deg. F.	Brinell Hardness Test	Percentage		Melting Temp. Deg. F.	Brinell Hardness Test
Tin	Lead			Tin	Lead		
0	100	618.8	3.9	60	40	368.6	14.6
10	90	577.4	10.1	66	34	356.0	16.7
20	80	532.4	12.16	70	30	365.0	15.8
30	70	491.0	14.5	80	20	388.4	15.2
40	60	446.0	15.8	90	10	419.0	13.3
50	50	401.0	15.0	100	0	466.0	4.1

Common or plumber's solder consists of *one part of tin to two parts of lead, and melts at* 441° *Fahr.* It is used by plumbers for ordinary work, and occasionally for electrical work where wiped joints are required, for instance, in large lead covered work. Medium or fine solder consists of equal parts of tin and lead, or *half and half*, and melts at 370° Fahr. This solder is always used for soldering joints in copper conductors, and for soldering lead sleeves on lead covered wires.

In the table which follows will be found the proper solder and flux to use with various metals.

Soft Solders and Fluxes for Various Metals

Metal to be Soldered	Flux	SOFT SOLDER					
		Tin	Lead	Zinc	Aluminum	Phosphor tin	Bismuth
Aluminum........	Stearin	70		25	3	2	
Brass..........	Chloride of zinc, rosin, or	66	34				
Gun metal.....	Chloride of zinc, rosin, or	63	37				
Copper........	Chloride of ammonia....	60	40				
Lead...........	Tallow or rosin.......	33	67				
Block tin.......	Chloride of zinc........	99	1				
Tinned steel.....	Chloride of zinc or rosin	64	36				
Galvanized steel..	Hydrochloric acid	58	42				
Zinc...........	Hydrochloric acid	55	45				
Pewter	Gallipoli oil........	25	25				50
Iron and steel ...	Chloride of ammonia....	50	50				
Gold...........	Chloride of zinc..	67	33				
Silver..........	Chloride of zinc...... .	67	33				
Bismuth.........	Chloride of zinc.	33	33				34

Hard Solders.—The various solders known as "hard" solders are used for joining such metals as copper, silver and gold, and such alloys as brass, German silver, gun metal, etc., which require a strong joint, and often a solder the color of which is near that of the metal to be joined.

Brazing compared with hard soldering (which is the term used by jewelers) ordinarily means that silver solder is used, whereas, brazing is generally understood to mean the joining of metals by a filler of brass.

A distinguishing characteristic of hard soldering is that a soldering bit cannot be used as in soft soldering because of the excessive temperature (red heat) which necessitates a blow pipe, gas forge, coke, or charcoal fire. The chief advantage of a brazed joint is its superior strength.

The following table gives the various hard solders, proper flux, and metals for which they are suited.

Hard Solders and Fluxes for Various Metals

Metal to be soldered	Flux	HARD SOLDER			
		Copper	Zinc	Silver	Gold
Brass, soft.........	Borax............	22	78		
Brass, hard.........	Borax............	45	55		
Copper.............	Borax .	50	50		
Gold...............	Borax....	22		11	67
Silver..............	Borax	20	10	70	
Cast iron...........	Cuprous oxide........	55	45		
Iron and steel.	Borax.....	64	36		

As will be noted from the table, most of the hard solders are alloys of copper and zinc. An easily fusible hard solder may be made of one part copper to two parts zinc, this, however, makes a joint that will be weaker than when an alloy more difficult to melt is used.

A hard solder that is readily melted is made of 44% copper, 50% zinc, 4% tin, and 2% lead.

A hard solder for the richer alloy of copper and zinc may be produced from 53 parts copper and 47 parts zinc.

When alloys containing much lead are used the strength of the joint is decreased because lead does not transfuse with brass.

The effect of tin is to increase the brittleness of the solder.

Miscellaneous Solders.—In addition to the solders already given, there are a number that are of value for various purposes.

Very Hard Yellow Solders.—The following formulæ make excellent hard solders for all purposes where a high melting point is required:
No. 1. Copper, 58 parts; zinc, 42 parts.
No. 2. Sheet brass, 85.42 parts; zinc, 13.58 parts.
No. 3. Brass, 7 parts; zinc, 1 part.
No. 4. Copper, 53.3 parts; zinc, 43.1 parts; tin, 1.3 parts; lead, 3 parts.

The hardest solders are given first. The following four have lower melting points than those above, and are more suitable where it is desired to solder brass alone.

No. 5. Brass. 66.66 parts; zinc, 33.34 parts.
No. 6. Brass, 50 parts; zinc, 50 parts.
No. 7. Brass, 12 parts; zinc, 4 to 7 parts; tin, 1 part.
No. 8. Copper, 44 parts; zinc, 49 parts; tin, 3.2 parts; lead, 1.2 parts.

Silver Solders.—These are not, as might be inferred from the name, employed only for the purpose of joining silver, but because of their great strength and resistance are used for many other metals. Like all other solders, they may be divided into the two groups; soft and hard. Silver solders are usually employed in the shape of wire, narrow strips, or filings. The following are especially adapted to soldering silverware:

Soft Solders

No. 4. Silver, 2 parts; brass, 1 part.
No. 5. Silver, 3 parts; copper, 2 parts; zinc, 1 part.
No. 6. Silver, 10 parts; brass, 10 parts; tin, 1 part.
The following silver solders are suitable for cast iron, steel and copper:
No. 1. Silver, 10 parts; copper, 10 parts.
No. 2. Silver, 20 parts; copper, 30 arts; zinc, 10 parts.

In addition to the various silver solders aready given, two other formulæ should be included.

No. 1. Yellow brass, 70 parts; zinc, 7 parts; tin, 11½ parts.

No. 2. Silver, 145 parts; brass (3 copper, 1 zinc), 73 parts; zinc, 4 parts.

Hard Solders

No. 1. Copper, 1 part; silver, 4 parts.
No. 2. Copper, 1 part; silver, 20 parts; brass, 9 parts.
No. 3. Copper, 2 parts; silver, 28 parts; brass, 10 parts.

Miscellaneous Silver Solders

Solder for silver plated work: No. 1. Fine silver, 2 parts; bronze, 1 part. No. 2. Silver, 68 parts; copper, 24 parts; zinc, 17 parts.

Solder for silver chains: No. 1. Fine silver, 74 parts; copper, 24 parts; orpiment, 2 parts. No. 2. Fine silver, 40 parts; orpiment, 20 parts; copper, 40 parts.

Resoldering silver solders: These siiver solders are for resoldering parts already soldered. No. 1. Silver, 3 parts; copper, 2 parts; zinc,

1 part. No 2. Silver, 1 part; brass, 1 part; or, silver, 7 parts; copper, 3 parts; zinc, 2 parts.

Readily fusible silver solder for ordinary work: Silver, 5 parts; copper, 6 parts; zinc, 2 parts.

French solders for silver: No. 1, for fine silver work: Fine silver, 87 parts; brass, 13 parts. No. 2, for work 792 fine: Fine silver, 83 parts; brass, 17 parts. No. 3, for work 712 fine: Fine silver, 75 parts; brass, 25 parts.
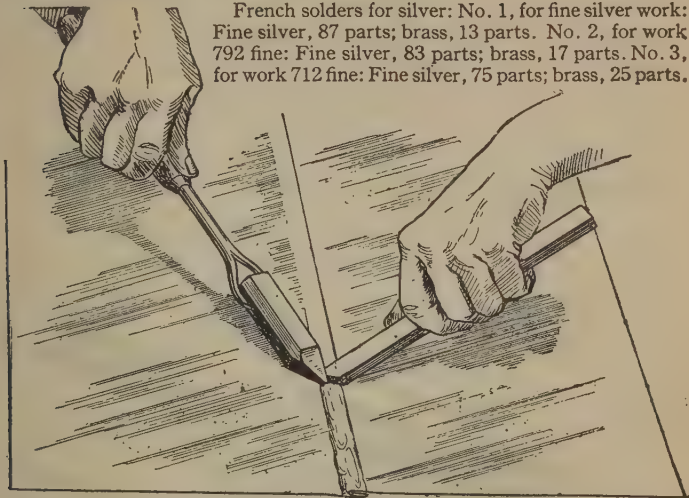
FIG. 6,375.—Ordinary soldering bit and method of using same in soldering a lock seam. All the surfaces which come into contact, in the inside of the seam, must be thoroughly cleaned before the folding is done. When the metal is turned upon one side, as in the case of turned copper, the folds are turned so that the turned surface will face each other. If the copper be without turning, although not strictly necessary to turn the surfaces that will cover inside of the seam. Secure sheets in place and close seams with a mallet. Apply flux and solder as shown. When the metal becomes hot the solder will *sweat* and disappear into the seam. The bit should always be kept sufficiently hot to cause the solder to disappear into the seam.
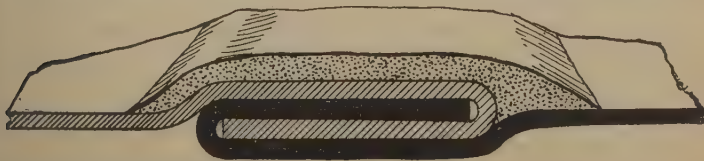
FIG. 6,376.—Enlarged section of lock seam.

No. 4, for work 633 fine: Fine silver, 66 parts; brass, 34 parts. No. 5, for work 572 fine: Fine silver, 55 parts; brass, 45 parts.

German Silver solders.—German silver is a very hard alloy of copper (50 to 60%), nickel (15 to 25%), and zinc (15 to 20%). A German silver containing 1 to 2% of tungsten is called *platinoid*. These alloys have a high electrical resistance, platinoid being higher than the other varieties of German silver; the resistance increases uniformly between 32° and 212° Fahr.

German silver solders possess considerable strength, and are often used for soldering steel. The color is very similar to that of steel.
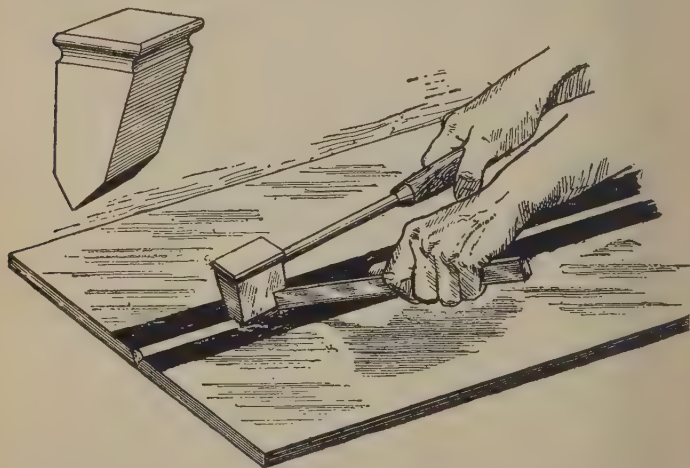
FIGS. 6,377 and 6,378.—Hatchet type soldering bit and method of using same in making a V or groove joint.

In preparing German silver solders, the copper is melted first, and then the zinc and nickel added simultaneously.

Soft German Silver Solders

No. 3. Copper, 4.5 parts; zinc, 7 parts; nickel, 1 part.
No. 4. Copper, 35 parts; zinc, 56.5 parts; nickel, 8.5 parts.
The following No. 5 formulæ given by Kent is similar to No. 4.
No. 5. Copper, 38 parts; zinc, 54 parts; nickel, 8 parts.

Hard German Silver Solders

These solders, sometimes called steel solders, contain a large proportion of nickel and are very strong. They require a very high heat for melting, and usually cannot be fused without the aid of a bellows or blast.

No. 1. Copper, 35 parts; zinc, 56.5 parts; nickel, 9.5 parts.
No. 2. Copper, 38 parts; zinc, 50 parts; nickel, 12 parts.

In soldering German Silver articles the solder is usually applied in the form of a powder or in very small pieces or lumps.

The solder may be powdered in a mortar if taken from the fire at the right temperature, when it is brittle. This operation is a somewhat difficult one, and so the usual, and perhaps the best plan, is to cast it in the the form of a bar or cylinder and then place the latter in a turning lathe, and adjust the tool so that fine shavings are cut off. The shavings are then heated until they become brittle, at which stage they are easily pulverized in a mortar.

Gold Solders.—The hard solder or gold solder which the jeweler frequently requires for the execution of various works, not only serves for soldering gold ware, but is also often employed for soldering fine steel goods, such as spectacles, etc. Fine gold is only used for soldering articles of platinum. The stronger the alloy of the gold, the more fusible must be the solder. Generally the gold solder is a composition of gold, silver, and copper. If it is to be very easily melted, a little zinc may be added. The shade of the solder is regulated by varying the proportions of silver and copper.

No. 1. For 18 carat gold: Gold (18K), 9 parts; silver, 2 parts; copper, 1 part.

No. 2. For 16 carat gold: Gold (16K), 24 parts; silver, 10 parts; copper, 1 part.

No. 3. For 14 carat gold: Gold (14K), 25 parts; silver, 25 parts; brass, 12½ parts; zinc, 1 part.

Aluminum Solders.—In soldering aluminum it is necessary previously to tin the parts to be soldered. This tinning is done with the iron, using a composition of aluminum and tin. A pure aluminum soldering bit should be used. To prepare an aluminum solder, first melt the copper, then add the aluminum gradually, stir well with an iron rod, next add the zinc and a little tallow or benzine at the same time. After adding the zinc do not heat too strongly. To avoid volatilization of the zinc, according to *Machinery*, the following aluminum solders have been successfully used:

Aluminum Solders

Tin	Aluminum	Zinc	Copper	Bismuth	Lead	Phosphor Tin*	Silver	Antimony	Cadmium	Magnesium
95.00				5.00						
78.50	2.00	19.00			0.50					
	66.70						33.30			
20.00	70.00						10.00			
97.00				3.00						
	6.00	89.50	4.50							
71.25	2.25	26.00				0.50				
60.00	4.00	8.00	4.00		12.00		12.00			
37.50		25.00	37.50							
	8.00	92.00								
30.00		20.00							50.00	
80.00	2.25	17.00				0.75				
66.00	15.50			9.00				7.00	†	2.25
15.50	2.50	78.25			2.50	1.25				
	20.00	65.00	15.00							
49.05		20.31	1.15		26.06			3.43		
30.00	70.00									
	4.00	94.00	2.00							
85.10	10.80								1.35	2.75
60.00		15.00		5.00	10.00			5.00		‡
86.00				14.00						
98.00	1.00			1.00						
20.00	70.00		10.00							
48.00	2.00	27.00			23.00					
90.00	5.00			5.00						
84.95				15.05						

*10% phosphorus.   †This solder also contains 0.25% vanadium.
‡This solder also contains 5% chromium.

Novel's solders for aluminum as given by Kent are as follows:
Tin   100 parts, lead 5 parts; melts at 536° to 572° Fahr.
Tin   100 parts, zinc 5 parts; melts at 536° to 612° Fahr.
Tin 1,000 parts, copper 10 to 15 parts; melts at 662° to 842° Fahr.
Tin 1,000 parts, nickel 10 to 15 parts; melts at 662° to 842° Fahr.

Novel's solder for aluminum bronze: Tin 900 parts; copper 100 parts; bismuth 2 to 3 parts. It is claimed that this solder is also suitable for joining aluminum to copper, brass, zinc, iron and nickel.

Soldering Fluxes.—The word *flux*, means a *substance applied to a metal to make solder flow readily on its surface.*

The action of a flux is largely that of cleaning the surface, and of reducing any oxide on the surface to the metallic state.

If a piece of sheet copper be carefully cleaned by means of emery cloth and heated over a gas flame, the surface will be seen to tarnish rapidly and assume a dark brown appearance. A small piece of resin dropped on the surface will melt, and when the liquid runs, the initial brightness of the surface will be found to reappear.

There are a number of flux suitable for various kinds of soldering, but pine amber resin is the best for electrical work as it does not cause corrosion. A corrosive flux, such as zinc chloride solution (killed spirits) should be strictly excluded from any electrical work. The nature of the solder often determines the flux.

The following table will serve as a guide in the selection of the ordinary fluxes.

Flux Table

Metals to be soldered	Flux	Metals to be soldered	Flux
Iron Turned iron Copper and brass	Borax Rosin Sal-ammoniac	Zinc Lead Lead and tin	Chloride of zinc Tallow or rosin Rosin and sweet oil

Resin.—This substance, one variety being called rosin, is difficult to define. It is undoubtedly an exudation from the trunk and limbs of

NOTE.—*On electrical work* the Underwriters' Code permits the use of a flux composed of chloride of zinc, alcohol, glycerine, and water. This preparation is easily applied and remains in place. It permits the solder to flow freely and is not highly corrosive. This flux is made as follows: Zinc chloride, 5 parts; alcohol, 4 parts; glycerine, 3 parts. Anhydrous zinc chloride crystals should be used desolved in alcohol. The glycerine makes the flux adhesive. To prevent the alcohol igniting, the mixture may be diluted with water. There are a number of prepared flux on the market, but are not to be recommended because of the ridiculously high prices demanded. *For electrical work, especially when very small wires are used, rosin should be insisted upon to avoid any corrosion.* No one flux can be assigned to any one metal as being peculiarly adapted or fitted to that metal for all purposes. The nature of the solder often determines the flux. The following fluxes are extensively used.

trees, but these exudations vary so much in all their properties that the terminology of them is wide, complicated and in some cases, contradictory.

Rosin solidifies after exudation from the tree and is insoluble in water, but soluble in alcohol.

Colophony, or rosin, is the kind of resin used as a flux, and consists of other coagulated exudation obtained from cuts in the bark of trees belonging to several species of Pinus, largely grown in America, and on the west coast of France. It comes in lumps but can be granulated by grinding in a coffee grinder or simply by hammering.

The resin may be sprinkled over the surface to be soldered or may be applied in liquid form by dissolving in alcohol. It is used as a flux for brass, copper, gun metal, lead, tinned steel.

Chloride of Zinc.—This flux, which may be used for brass, copper, gun metal, block tin, tinned steel, gold, silver, bismuth, is prepared as follows: Place three parts of hydrochloric (muriatic) acid and one part of water in a glass, wooden, or lead vessel, and add pieces of zinc as long as the acid attacks the zinc. Put in the zinc gradually to prevent "boiling over." Care should be taken to get a saturated solution, that is, to add all the zinc that the solution will dissolve. After settling, the clear solution should be poured off and the latter is then ready for use.

Another flux made with zinc chloride that is especially adapted to the soft soldering of iron and steel (because it does not make rust spots) consists of the ordinary zinc chloride with addition of one-third spirits of sal-ammoniac and one-third part rain water; the mixture is filtered before using.

A formula which dispenses with the use of chloride of zinc consists of: Water, 80%; lactic acid, 10%; glycerine, 10%.

An acid free soldering fluid consists of: 5 parts chloride of zinc, 25 parts of boiling water. Another: 20 parts chloride of zinc; 10 parts ammoniac chloride; 100 parts boiling water. Another formula consists of chloride of zinc, 1 drachm; alcohol, 1 ounce.

Rosin and Tallow.—A mixture commonly used consists of rosin and tallow with the addition of a small quantity of sal-ammoniac. This is adapted to tinned ware, because of the ease with which it may be wiped off the surface after soldering.

Another mixture consists of: 1½ lbs. olive oil; 1½ lbs. tallow; 12 oz. pulverized rosin. Let the mixture boil up and when cool add 1⅜ pints of water saturated with pulverized sal-ammoniac, stirring constantly.

Soldering Grease.—In a pot of sufficient size and over a slow fire, melt together 500 parts of olive oil and 400 parts of tallow, then stir in slowly 250 parts of rosin in powder, and let the whole boil up once. After cooling, add 125 parts of saturated solution of sal-ammoniac while stirring; use when cold.

Ammonia Soap.—Mix finely powdered rosin with strong ammonia solution. This is suitable for soldering together copper wires for electrical conduits.

Soldering Fat for Iron.—Olive oil, 50 parts; sal-ammoniac, 50 parts.

Soldering Fat for Aluminum.—Melt together equal parts of rosin and tallow, half the quantity of chloride of zinc being added to the mixture.

Soldering Salt.—Mix equal parts of neutral chloride of zinc, free from acid, and powdered sal-ammoniac. When required for use, 1 part of the salt should be dissolved in 3 or 4 parts of water.

Soldering Paste.—Consists of neutral soldering liquid thickened with starch paste. In using apply more lightly than the soldering liquid.

Borax.—This flux is most frequently used for hard soldering. It should be applied to the soldering seam either dry or stirred to a paste with water. It is advisable to use borax which has been dried by heat (calcined borax).

For soldering steel on steel, or iron on steel, melt in an earthen vessel: borax, 3 parts; colophony, 2 parts; pulverized glass, 3 parts; steel filings, 2 parts; carbonate of potash, 1 part; hard soap, powdered, 1 part. Flow the melted mass on a cold plate of sheet iron, and after cooling, break up the pieces and pulverize them. This powder is thrown on the surfaces a few minutes before the pieces to be soldered are brought together. The borax and glass dissolve, liquefying all impurities, which, if they were shut up between the pieces soldered, might form scales.

Cryolite.—Finely powdered cryolite is suitable for hard soldering copper and copper alloys, or a mixture of 2 parts powdered cryolite, and 1 part phosphoric acid may be used. For hard soldering of aluminum bronze, a mixture of equal parts of cryolite and barium chloride is used.

Muller's Hard Soldering Liquid.—This consists of equal parts of phosphoric acid and alcohol (80 per cent.).

Dry Soldering Preparation.—A good preparation consists of two vials, one of which is filled with chloride of zinc and the other with ammonium chloride. To use, dissolve a little of each salt in water, apply the ammonium chloride to the object to be soldered and heat the latter until

it begins to give off vapor of ammonium, then apply the other, maintaining the heat in the meantime. This answers for very soft solder. For a harder
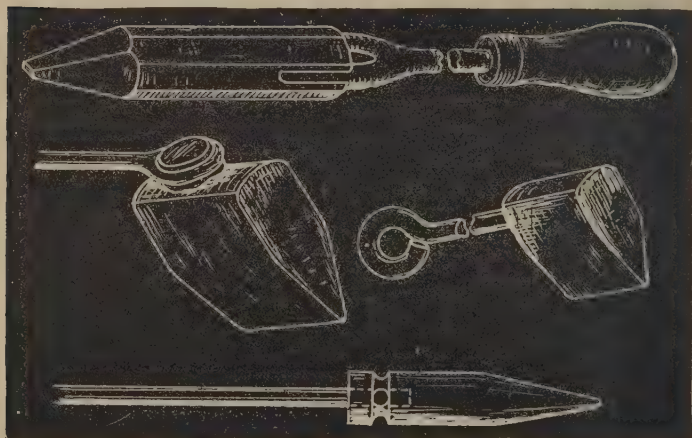
FIGS. 6,379 to 6,382.—Various soldering bits, or so called "irons." Fig. 6,379, ordinary edge bit; figs. 6,380 and 6,381 hatchet bit; fig. 6,382, pointed bit.
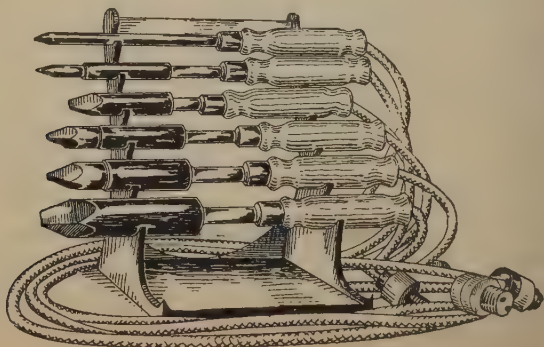
FIG. 6,383.—Nest of electric soldering bits, showing various forms and sizes

solder dissolve the zinc in a very small portion of the ammonium chloride solution (from ¼ to ½ pint).

Soldering Bolts or Bits.—The erroneously called soldering "iron" or bit consists of a large piece of copper, drawn to a point or edge and fastened to an iron rod having a wooden
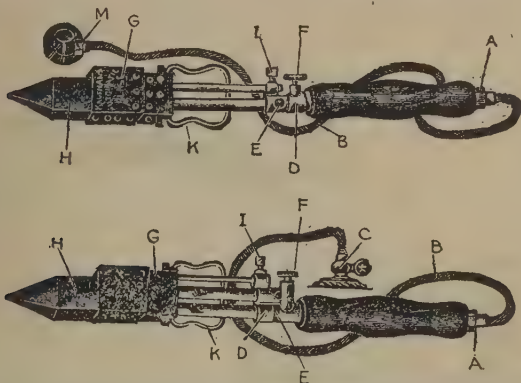
Figs. 6,384 and 6,385.—Kageman self-heating gas soldering bit for bench work. Fig. 6,384, single torch; fig. 6,385, double torch. Any shape or weight of copper point for any class of work may be easily substituted by means of a set screw I. One end of a flexible tubing is attached to the nozzle or male screw near the handle A, and the other end is connected to the gas main M. (⅝ main preferred.) Before lighting, close the Bunsen holes E, by means of the air slide D, open the governor F, turn on gas main M, light near copper point at G, and gently open Bunsen holes by means of slide D. If flame appear within chamber E, turn off gas, slightly close holes by means of slide D, and light again. Shut off gas at main cock M. Where the gas main is already installed it is advantageous to bore a hole in the bench near the wall, connect a flexible metallic tubing to the gas main, pass tubing through the hole and fasten tubing to the underside near the outer edge of the bench. In this way the hose will hang freely and will hardly be noticeable. The soldering iron can be used away from the bench at any desired distance, depending upon the length of the tubing. The double torch, fig. 6,385, has two burner tubes generating two short but intensely hot blasts. The double flame is intended to heat heavy coppers quickly, and when the desired temperature is reached one flame is shut off by a half turn of the governor, the remaining flame keeping the point at a study temperature throughout the day. For smaller coppers one flame is sufficient. When a large heating power is required it is often desirable to use both blasts throughout the day.

handle as shown in fig. 6,379. There is a variety of bits which may be classed

1. With respect to their shape, or construction as

    a. Pointed;   *c*. Hatchet;

    b. Grooved;   *d*. Reservoir.

2. With respect to the method of heating, as

    a. Externally heated; *b*. Internally heated $\begin{cases} \text{electrically, or by} \\ \text{gasoline torch.} \end{cases}$
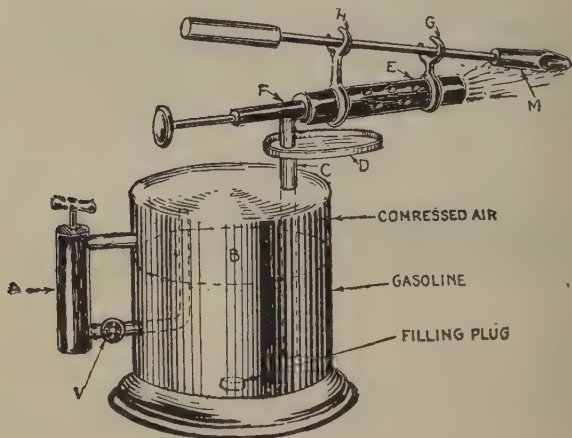
FIG. 6,386.—Gasoline torch with rests for holding soldering bit. *In construction* A. is a hand air pump, which may have automatic, or hand operated valve; B, is the reservoir containing gasoline and compressed air, the latter being furnished by the pump. A valve V, prevents leakage of the compressed air through pump. A pipe C, projects to bottom of reservoir, as indicated by dotted lines, and connects with vaporizer E, through needle valve F. A trough D, is for holding a small quantity of gasoline to heat vaporizer E, in starting. Two supports H and G, clamped to the vaporizer support a soldering bit so that it will rest in the flame in heating. *In operation,* the reservoir is filled about two-thirds full through filler plug and the pump given a few strokes to compress air in the top of reservoir. After heating vaporizer E, with a little gasoline placed in D, needle valve F, is opened slightly. The gasoline under pressure in the reservoir will flow through needle valve F, into the vaporizer and ignite. As the vapor becomes hotter the valve may be given more opening and when fully heated an almost colorless flame of great heat will issue from the end of the vaporizer. Air supply is admitted into the vaporizer through the small holes shown. In attaching the supports H, G, care should be taken not to cover any of the air holes, because this will cause a poor flame.

The various types of bit are shown in the accompanying cuts.

A heavy bit is preferable for joining work, as one weighing less than two pounds does not retain the heat long enough.
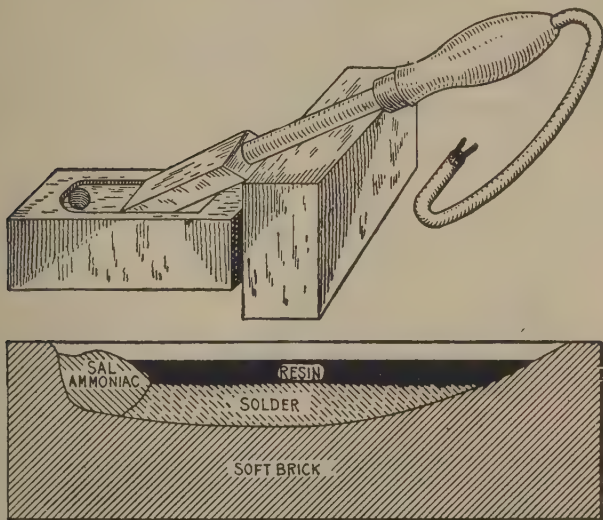
Figs. 6,387 and 6,388.—Tinning block for electric soldering tool. *It is made* with two soft bricks. One brick is used to support the soldering tool, and the other to contain the tinning material and to furnish a material which will keep the copper bit bright enough to receive its coating of "tin." Fig. 6,388 represents a section of the tinning brick, which is scooped out on top as shown by the lower line. Into one end of the hollow in the brick, some sal-ammoniac is placed to help tin the copper bit. Sal-ammoniac is a natural flux for copper and aids greatly in keeping the tool well tinned. Next, some melted solder is run into the hollow of the brick, and lastly enough resin to fill the cavity nearly to the top. When the tool is not in use, the electricity is switched off and the tool permitted to lie in the resin. If it be desired to repair the tin coating a little when the tool is in use, the latter is rubbed on the brick below the layer of solder, and the layer of resin. If the tool be in very bad condition, it may be pushed into the sal-ammoniac once or twice and then rubbed in the solder again. It requires but little heat to keep the brick and its contents ready for use. In fact, the brick is a fair insulator of heat and partly prevents the escape of heat from one side of the tool. When momentarily not in use, the tool remains in the solder which becomes melted underneath the layer of resin. When the copper bit becomes too hot, it will begin to volatilize the resin, thus calling attention to this fact, whereupon the electricity should be turned off from the tool.

Tinning the Bit.—Preliminary to soldering, the bit must be coated with solder, this operation being known as "tinning " To tin a soldering bit, heat it in a fire or gas flame until hot enough to melt a stick of solder rapidly when it is lightly pressed against it.

When the bit is at the right temperature, the heat can be felt when it is held close to the face. When hot enough clean up the surface of the copper with an *old* file.
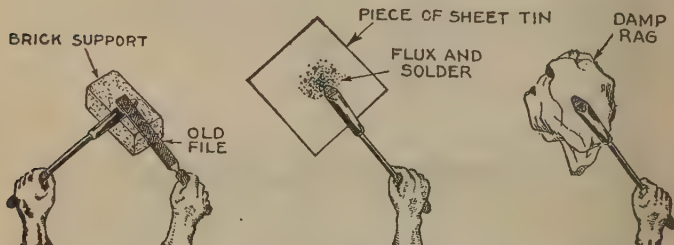
FIGS. 6,389 to 6,391.—"Tinning" the bit. Fig. 6,389, cleaning bit by filing working surfaces with an old file; fig. 6,390, rubbing the bit on the flux and solder, which may be conveniently placed on a piece of sheet tin as shown; fig. 6,391, removing surplus solder by giving each side of the bit a quick stroke over a damp rag.

If the temperature be too high, the copper surface will be found to tarnish immediately, in which case the soldering bit must be allowed to cool slightly and the cleaning repeated. When the surface only tarnishes slowly a little flux is sprinkled upon it, and then rubbed with a stick of solder.

After the molten metal has spread over the whole of the surface which it is desired to tin, the superfluous solder is wiped off with a clean damp rag.

The surface should then present a bright silvery appearance when properly tinned.

The operation of tinning the bit is shown in figs. 6,389 to 6,391. Once a soldering bit has been well tinned care should be taken not to overheat it. If the bit at any time reach a red heat it will be necessary to repeat the whole tinning process before it is fit to be used again. No good work *can be done with an untinned or **badly tinned** bit*.

If the bit be forgotten and left in the fire, heat to redness and then plunge into cold water, when most of the hard oxidized surface will scale off. A soft coal fire will quickly destroy the tinning.
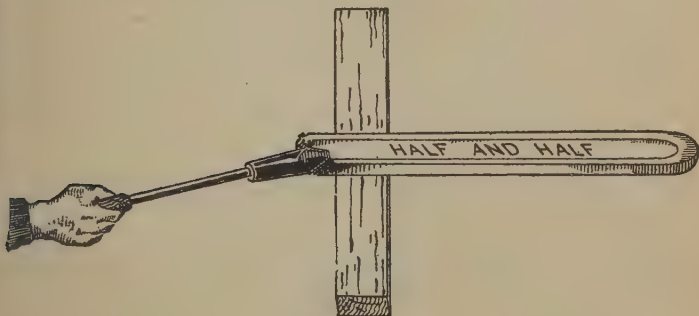
Fig. 6,392.—Picking up solder with a hot bit. This is the proper method for small work. Rest the bar of solder on some support as a brick or piece of wood and touch it with the end of the hot bit. Some of the solder will melt and remain on the bit. It is then transferred to the part to be soldered, and if the surfaces be in proper condition and fluxed when the bit touches the surfaces, the solder will leave the bit and cover the surfaces. *In picking up solder* from the stick, care should be taken not to leave the bit in contact with the solder too long or some of it will drop off. The larger the bit and area tinned, the more solder will the bit hold.

Soft Soldering.—The theory of soft soldering is that: *as the solder adheres to and unites with the surface of the copper when the bit is tinned, so will it adhere to and unite the surfaces of the metals to be soldered.*

Soft soldering, as well as hard soldering, or brazing, consists

in welding together two or more pieces of similar or dissimilar metals by means of another metal of lower melting point.

In order to solder successfully wire joints, the following instructions should be followed:

1. Clean and tin the bit as shown in figs. 6,389 to 6,391.

2. Heat the bit in the fire until it reaches the right temperature. Do not try to solder a joint with a bit so cool that it only melts the solder slowly, nor with one so hot that it gives dense clouds of smoke when in contact with rosin. Burned rosin must be regarded as dirt.

3. Remove the bit from the fire and hold it, or preferably support it on a brick or block of other material which does not conduct heat readily.

4. Wipe the surface clean with a rag. Apply solder until a pool remains on the flat surface, or in the groove, if a grooved bit be used.

5. Sprinkle with rosin, lay the joint in the pool of solder and again sprinkle with rosin.

6. Rub the joint with a stick of solder so that every crevice is thoroughly filled.

7. Remove the bit, and lightly brush superfluous solder from the bottom of the joint. See that no sharp points of solder remain which may afterwards pierce the insulation.

When the joint is first placed on the bit, the solder should run up into the joint. This will occur only when the joint is well made and thoroughly cleaned, and if the workmanship be perfect it is even possible to fill the joint completely by feeding in solder below the joint as it melts and runs up into the joint.

A well soldered joint should present a smooth, bright appearance like polished silver. Wiping the joint before it cools destroys this appearance, and is also liable to produce roughness, which is detrimental to the insulation.

Soldering with a Torch.—The flame is directed on the middle of the joint, and when a sufficient rise of temperature has taken place to melt the solder readily, the joint is rubbed with rosin and solder alternately until it is thoroughly saturated with solder. The usual precaution of brushing any points of solder off the joint with a clean rag must, of course, be taken.

In using the torch there is considerable danger of damaging the insulation with the flame. This may be minimized by wrapping the end of the insulation with selvedge tape before soldering. When big joints are being made it is sometimes advisable to wet the tape in order to prevent the conduction of heat along the copper to the insulation.

Sweating.—In this operation *the surfaces are cleaned, heated, and covered with a film of solder.* The soldered surfaces are then placed together and heated by passing the bit over the outside surface until the solder melts and unites the two surfaces.

Sweating is often employed for the temporary holding together of work which has to be turned or shaped, and which could not be so conveniently held by other methods. After

Figs. 6,393 to 6,397.—*Sweating.*—When two surfaces are to be united by sweating, first see that the surfaces are perfectly clean, then flux as in fig. 6,396. Put a piece of tinfoil over the surface and the other surface on top. They should be held firmly together by a clamp or other means and heated as in fig. 6,397 by a hot bit, or if the metal have considerable thickness, by a torch until the solder melts. When cool, the surfaces will be found to be firmly united.

having been turned or shaped, the separation of the parts is readily effected by the aid of heat.

Babbitting Boxes.—Although some special machines are provided with ball bearings, most dynamos and motors have plain babbitted bearings, accordingly electricians and repair men should know how to babbitt a box if occasion arises for such operation.

Formerly, bearings for the journals of machinery were constructed of *brass or other alloys*, for the purpose of minimizing friction. Hard cast

iron, which afforded an admirable surface becoming glazed over with a sort of skin after a little use, while efficient for sliding surfaces, had to be avoided for journals, as irreparable damage might be done to the bearing when overheated. Later practice evolved the idea of using a softer or elastic metal, popularly and *erroneously* known as *anti-friction metal*, which would accommodate itself to inequalities of the surfaces in contact, thus working with far less friction than iron or bronze; while on the other hand it would be much cheaper than a copper tin alloy.
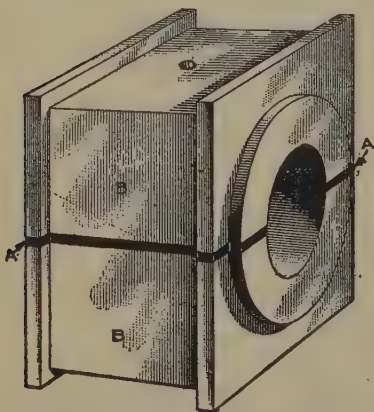
FIG. 6,398.—Sweating brasses. When brasses are sweated together, liners A,A, are sometimes placed between them, as shown, to allow for wear when they are in the machine. The faces of the brasses and liners are planed smooth and rubbed bright. They are then heated in the forge, and when hot, the brasses fluxed with sal-ammoniac and tinned by the method employed in tinning the soldering copper. The liners, if of iron, are fluxed with borax and tinned. If not heavy enough to make a tight joint, they are weighted down until cold. When the pieces have been bored out and finished in the machine shop, they are melted apart and the liners taken out, a number of thin liners being substituted.

Of the various so called anti-friction metals, Babbitt is extensively used. This is a soft white metal composed of tin, copper and antimony. Many different compositions of these metals are used for Babbitt metal; the alloy originated by Isaac Babbitt was composed of tin, 45½ parts; copper, 1½ parts; antimony, 13 parts; lead, 40 parts.
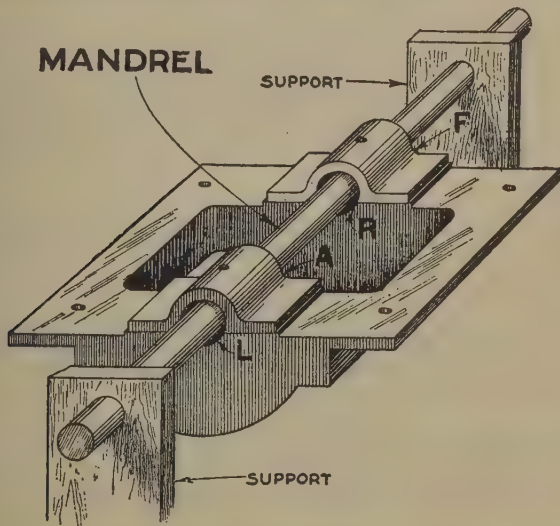
Fig. 6,399—Babbitting engine main bearings; view showing mandrel in place ready for pouring. The ends L,A,R,F, of the bearings are closed by putting on close fitting wood blocks so that the molten metal will not run out.

In the beginning this proportion was used for all purposes, but it has since been found that there is no one composition that will bring equally good results in all kinds of machinery, hence the following different proportions are given:

Babbitt metal for light duty is composed of 89.3 parts of copper, 1.8 parts of antimony, 8.9 parts of lead.

Babbitt metal for heavy bearings is composed of 88.9 parts of copper, 3.7 parts of antimony, 7.4 parts of lead.

Lead and antimony have the property of combining with each other in all proportions without impairing the anti-fraction properties of either, the antimony hardens the lead, and when mixed in the proportions of 80 parts lead, by weight, with 20 parts antimony, no other known composition of metals possesses greater anti-friction or wearing properties or will stand a higher speed without heat or abrasion.

The operation of babbitting a box should be done in accordance with the following instructions to obtain good results.

1. Avoid overheating the babbitt, as this is destructive to the qualities of the metal and also entails a considerable loss on account of the dross or scum that has to be skimmed off the ladle.

To ascertain the proper temperature, the time honored test is to try it with a dry pine stick. The temperature should be such that the stick will char without catching fire. Cover the metal with powdered charcoal and put in the ladle a lump of sal-ammoniac.

Of course, it is sometimes necessary to heat the babbitt hotter than this to insure its running to all parts of the box when the section to be filled is thin, but if possible, in such cases, the box should be warmed up to prevent excessive chilling of the metal.

NOTE.—*The practice of lining journal boxes* with a metal that is sufficiently fusible to be melted in a common ladle is not always so much for the purpose of securing anti-friction properties as for the convenience and cheapness of forming a perfect bearing in line with the shaft without the necessity of boring it. Boxes that are bored, no matter how accurately, require care in fitting and attaching them to the frame or other parts of a machine.

NOTE.—*Cast iron soldering.*—A new process consists in decarbonizing the surfaces of the cast iron to be soldered, the molten hard solder being at the same time brought into contact with the red hot metallic surfaces. The admission of air, however, should be carefully guarded against. First pickle the surfaces of the pieces to be soldered, as usual, with acid, and fasten the two pieces together. The place to be soldered is now to be covered with a metallic oxygen compound, and any one of the customary fluxes, and heated until red hot. The preparation best suited for this purpose is a paste made by intimately mingling together cuprous oxide and borax. The latter melts in soldering and protects the pickled surfaces, as well as the cuprous oxide from oxidation through the action of the air. During the heating the cuprous oxide imparts its oxygen to the carbon contained in the cast iron and burns it. Metallic copper separates in fine subdivision. Now apply hard solder to the place to be united, which in melting, forms an alloy with the eliminated copper, the alloy combining with the decarburized surfaces of the cast iron.

2. If the box is to be babbitted with the shaft in position for a mandrel, be careful to get the shaft properly lined and central in the box.

To hold it in position, use an outside support if convenient, but if not, small pieces of lead hammered to the right thickness may be used to hold it at the proper height and in a central position. *It is not good practice,* however, to use the shaft for the purpose of casting the bearings, especially if the shaft be of steel, for the reason that the hot metal is apt to spring it; the better plan is to use a mandrel of the same size or a trifle larger for this purpose. For slow running journals, where the load is moderate, almost any metal that may be conveniently melted and will run free will answer the purpose. For wearing properties with a moderate speed there is probably nothing superior to pure zinc, but when not combined with some other metal it shrinks so much in cooling that it cannot be held firmly in the recess, and soon works loose.

3. The shaft should be smoked or greased so that the babbitt will not adhere to it.

4. The ends of the box should be stopped with clay or cardboard washers cut to snugly encircle the shaft and held to the face of the box, to prevent the babbitt escaping.

Liners made of cardboard should be inserted between the halves of the box and should touch the shaft on each side so that the box can be divided without trouble after the pouring is completed.

5. A small hole at one end will be sufficient to insure the lower part filling properly.

6. With a large box and shaft, it is best to pour the lower part first and then the upper one.

7. Care should be taken that there is no water or dampness in the box, as serious consequences may follow if this precaution be neglected.

A rusty box is likely to throw the babbitt, as water will be liberated when the hot metal is poured on it. A small lump of rosin dropped in the ladle just before pouring increases the fluidity of the metal somewhat and reduces the liability of the babbitt to explode when the interior is slightly damp, although no risks should be taken in this direction.

8. If the oil hole be used to pour through, it will be necessary to drill it out and cut the oil grooves after the box is taken apart.

9. If the babbitt be poured from the side, a plug of pine wood can be inserted in the oil hole down to the shaft to keep it clear.

10. The shaft is sometimes wrapped with a stout cord laid in a spiral direction to get the proper oil runs, but it is usually better to cut them afterwards with a round nose chisel.

Lead Burning.—This process, sometimes erroneously called
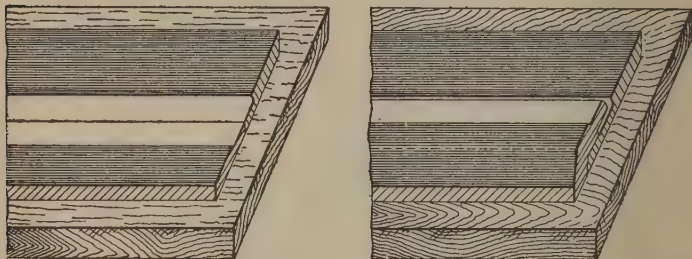
Figs. 6,400 and 6,401.—Preparation of butt and lap seams for lead burning. Fig. 6,400 shows the edges of a butt seam placed together on a piece of flat board, and the seam shaved ready for burning. The width of the shaving is governed by the thickness of the lead to be joined. For 5 lb. lead the rear should be about ⅜ inch wide, that is the edge of each piece should be shaved to a width of ³/₁₆ inch. Fig. 6,401 shows a lapped seam ready for burning. The face of the under side is shaved the width of the seam, and the over lead on the under side, as well as on the upper face, the width being a little less than the width of the seam for butt burning. The shaving is done with an ordinary shave hook and straight edge.

autogenous soldering, consists of *joining pieces of lead together by simply placing the edges to be joined close to, or overlapping each other, and then melting them so that they flow and intermingle with each other, forming one piece, and retaining the same condition of unison on solidifying.*

In some cases a strip of lead is melted at the same time as the edges; this makes a raised, and consequently a stronger seam. The process is useful only for joining lead to lead and

would not answer so well for joining lead to copper or to brass.

In lead burning, a hydrogen flame is used in connection with a jet of air, the hydrogen being produced in a machine or generator as explained fully in Guide No. 4, page 928, fig. 1,128.

ONLY TOP SIDE TINNED

A

SOLDERING SPLICE
IN WIRE

A
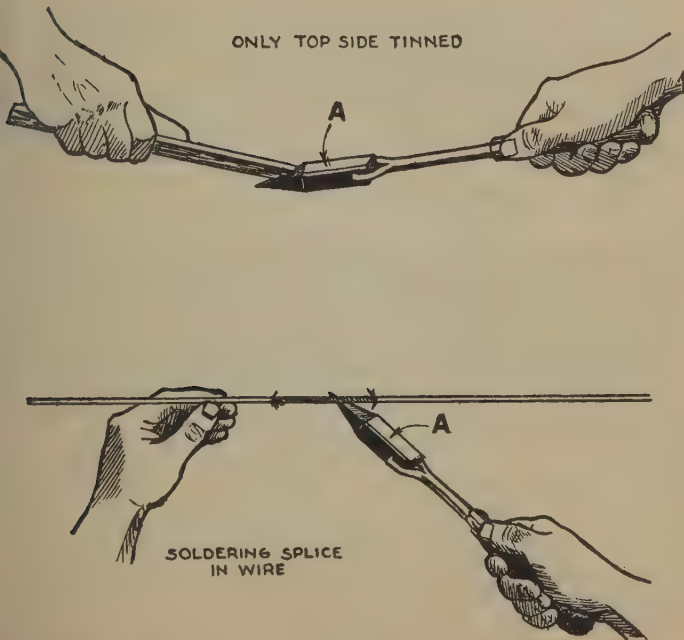
Figs. 6,402 and 6,403.—Overhead soldering. *The difficulty encountered* on such work is to retain the solder at the right place on the bit. This is accomplished by turning only one face of the bit. If bit be already turned on all four faces file bit clear down to copper on all but one side as side A, and apply solder as in fig. 6,402. The bit is now ready for overhead work and may be used without the solder leaving the working face or dropping on the floor below. Fig. 6,403 is an example of overhead soldering showing soldering of wire joint.

For joining lead sheets together by burning, it is essential that the pieces touch or overlap each other when in the horizontal position, and overlap when in either slanting, upright, or overhead positions. It is not necessary to *soil* the sides of the seams, because the lead will flow only where it is directed by the flame jet. No fluxes are necessary.

LEAD-STICK
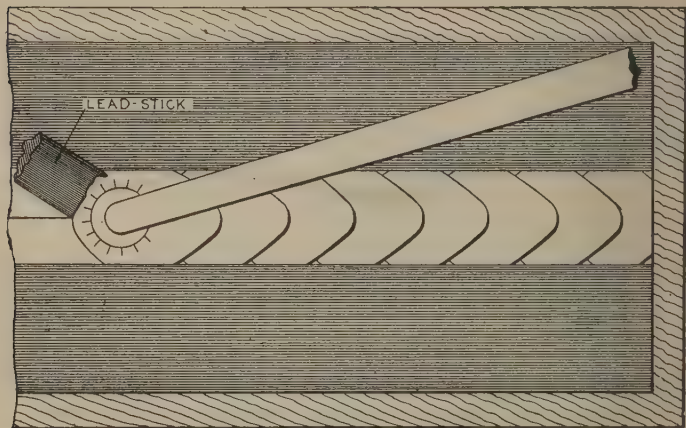
Fig. 6,404.—Process of burning a butt seam in two sheets of lead.

The details of preparation of butt and lap seams are shown in figs. 6,400 and 6,401.

To burn either of these seams, first regulate the gas and air cocks or the gas and oxygen cocks of the generator as the case may be, so as to obtain a "hard solid flame."

For flat butt burning, the end of a stick of lead should be held on the seam so as to be melted at the same time as the other lead, as shown in fig. 6,404.

Before beginning to burn the seam, a stick of lead should be held in the hand and the flame made to play upon it so as to ascertain the hottest part of the flame to apply to the seam.

If the flame tarnish or smoke the lead stick, more air or oxygen should be burned in.

Again if the lead turn to a silvery brightness, when the flame impinges, the heat will be right and the part of the flame to be used will be ascertained.

Now tack the two ends of the seam by melting little beads on them to hold the pieces in position.

The burning can now be started, beginning being made at the right hand end.

The flame is lifted immediately when the metal begins to flow and
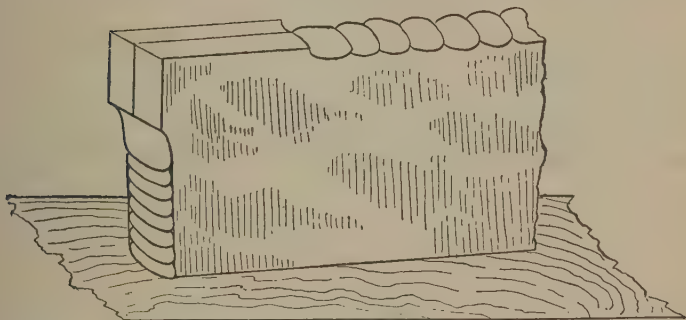
FIG. 6,405.—Edge burning. In this case no feed lead is necessary, but a slight jar has to be given to start the first bead on either the vertical or the horizontal seam.

reapplied at a distance of from $\frac{1}{8}$ to $\frac{1}{2}$ inch, according to the thickness of the lead being joined together, giving the appearance shown in fig. 6,404.

During the process of burning, the sheet lead will be expanded when the heat is applied, and being a poor conductor, the heat is not distributed to the adjoining sides of the seam, hence the heated parts will rise up and leave hollow spaces underneath. When this happens, leaving places where the lead does not rest in the board the lead melts more readily, with the result that a hole is made, through which the molten metal will flow. To prevent this, the lead should be held down with the end of the stick of feeding lead, which is held in the left hand.

NOTES

NOTE.—*The four principles of soldering* are as follows: 1, the soldering bit must be kept clean and well tinned; 2, a good soldering flux must be used; 3, the metals to be soldered must be thoroughly cleaned before the joint is made; 4, the joint must be heated above the melting point of the solder.

NOTE.—When a soldering bit is properly *tinned*, the end of the iron or tinned portion is bright and shiny the color of new tin. The bit must be kept in this condition to do satisfactory work.

NOTE.—*Soldering requires heat*. The heat may be supplied by a gas stove, coal stove or gasoline torch. The soldering bit must be kept clean and well tinned. A good soldering flux must be used. The metals to be soldered must be thoroughly cleaned, before the joint is made. The joint must be heated above the melting point of the solder. Soldering bits cannot be heated properly in the yellow or illuminating flame of the gas because it smokes the soldering bit, and also because it is not hot enough. They need a blue flame, the same as given off by a gas stove, but a good clean coal fire will do.

NOTE.—*To heat a soldering bit,* slip the pointed end down through the hole in the center of the burner of an ordinary gas stove so that the blue flame comes in contact with the large end of the iron. This method of heating does not burn the solder from the bit so quickly and the bit keeps hot longer.

NOTE.—*To determine when the soldering bit is hot enough,* try it by putting the solder to the point. If the solder melt as soon as it touches the bit, it is hot enough and ready to use. If the bit be overheated the tinning will be burned off and it must be retinned, or if the end of the bit become black and the black will not wipe off, the bit needs retinning.

CHAPTER 109

Lead Work

2. Joint Wiping

In the days when "plumbing was plumbing"[*] the prime ambition of the young plumber was to become an expert lead wiper. Although now, while lead pipe has been largely replaced by brass and steel pipe, the plumber should not underestimate the importance of ability in lead work.

To wipe a joint and make a good job of it requires a knowledge of the principles involved and considerable practice.

Judging the Solder.—The first requirement is the ability to judge the *quality* of the solder, that is, the plumber must know by its appearance when it contains the right proportions of lead and tin. To preserve these proportions it is necessary to keep the solder from overheating, because in overheating some of the tin will burn, thus destroying the correct proportions. The tin burns because its melting point is lower than that of the lead. The quality of the solder may be judged by pouring out a small quantity on a brick or stone and noting the color when it sets, also the number and size of bright spots on its surface. When the proportions are correct, there will

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[*]NOTE.—See fig. 5,999, page 1,220.

appear on a test sample (almost the size of a half dollar) about four small bright spots. The side of the solder next to the brick will be bright. Adding lead will reduce the size and number of spots; adding tin increases them. Thoroughly stir the solder before pouring out a test sample. The rate of cooling affects the appearance of the test sample; if cooled too quickly, the solder will appear *finer* than it really is.* When the tin burns it is indicated by the formation of dross on the surface, specks of which turn bright red and smoke. Too little tin in the solder will cause the solder to melt the lead pipe on which it is poured; it will burn the tinning of a brass ferrule or union and set free zinc from the brass which will mix with the solder and render it unfit for joint wiping.

The right heat of the solder is judged by the color or bloom on the surface of the molten solder, or by holding the ladle near the face.

An easier test for the beginner is to stir with a wooden stick; when at the right temperature it will char the stick, and if too hot, the stick will burn.

Proportioning the Solder.—Ordinarily, solder is made with twice as much lead as tin. In using solder, the numerous heatings and occasional overheating it receives results in losing some of the tin by burning and the solder is then sure to be *coarse*. It is necessary to add a little tin from time to time to make up this loss.

Since the tin is lighter than the lead it tends to float on top of the lead. Hence, unless the solder be stirred before dipping with ladle, an excess amount of tin will be removed. These two causes for loss of tin are emphasized by the following table:

*NOTE.—The term *fine* relates to the proportion of tin in the solder; the finer the solder, the greater the percentage of tin.

Properties of Lead and Tin

Ingredients	Melting Point	Specific Gravity	Weight	
			Per cu. in.	Per cu. ft
Lead	620° Fahr.	11.07 to 11.44	.4106	709.7
Tin	449° Fahr.	7.297 to 7.409	.2652	458.3

Solder composed of two parts lead and one part tin is called plumbers' solder and is suitable for wiping joints.

The following method of making it is recommended:

Take 100 lbs. good old lead or lead cuttings, run it down thoroughly, stir it up and take off all dirt or dross: then take 50 lbs. pure tin, let this run down, and when nearly all is melted and is a little cooler throw in ⅓ lb. of black rosin and stir well.

Heat to 600 degrees, which may be known by the burning of a bit of newspaper put in the pot. The solder is now hot enough and should be well stirred and then put into moulds.

Solder thus made melts at 440° Fahr.

Cleaning Solder.—In using solder it is frequently rendered unfit by

1. Overheating.
2. Falling unprotected and picking up foreign matter.

   a. Mechanically.
   b. Chemically.

Overheating as already explained causes loss of tin by burning thus destroying the correct proportion of tin to lead.

In the process of pouring solder in joint wiping, a certain amount falls from the joint. If this fall, say on a bench where it may mechanically pick

up zinc or brass filings and is returned to the pot, the entire contents of the pot will be rendered unfit for use until the zinc has been removed and the solder brought back to correct proportions.

In order to get rid of the zinc it is necessary to heat the solder to 773° Fahr, the melting point of zinc. The zinc being lighter than either lead or tin will when melted rise to the top and can then be skimmed off.*

When the zinc solder has been heated sufficiently to melt the zinc, throw in a lump of sulphur or rosin and stir, which will increase its buoyancy. The top will then consist of a mixture of lead oxide, putty powder,
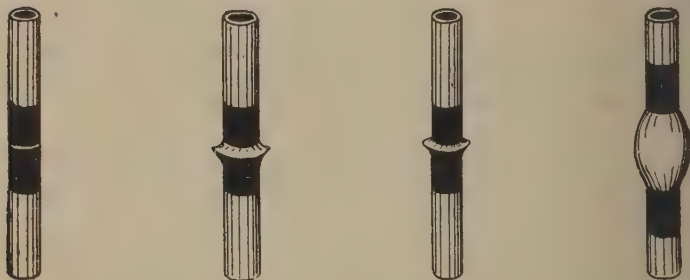
FIGS. 6,406 to 6,409.—Various joints. Fig. 6,406, *butt joint* made by squaring the ends, tinning one, and sweating the other to it by heating with torch; this is a comparatively weak joint fig. 6,407, *blow joint;* fig. 6,408, *copper bit joint,* the only difference between these is that the solder is floated by a torch in fig. 6,407, and by a bit in fig. 6,408, the latter joint being heavier than the former. Fig. 6,409, round wiped joint.

sulphur and zinc. Let cool to working point and stir in some tallow and rosin and again skim. The tin lost by overheating to remove the zinc should be replaced with more tin†. In removing zinc be careful not to heat the solder any more than necessary; never let the solder become "red hot" in daylight.

Preparing Joint for Wiping.—It is important that the ends of lead pipe to be joined be properly treated before wiping.

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*NOTE.—Zinc weighs 436.5 lbs. per cu. ft. as compared with 709.7 and 458.3 lbs. for lead and tin respectively.

†NOTE.—Lead oxidizes at 612° and tin forms putty powder at 428° Fahr.; the solder oxidizes at 440°.

The two essential requirements for satisfactory flow in service are: 1, that the ends of the pipes to be joined properly fit so that in pouring the solder it will not run through the joint and form an obstruction, and 2, that there be no sharp internal projection at the joint which would catch lint or any other foreign matter. In addition, the formation given to the ends of the pipes should be such as to form a socket into which the solder will flow, thus making the joint stronger than if merely built
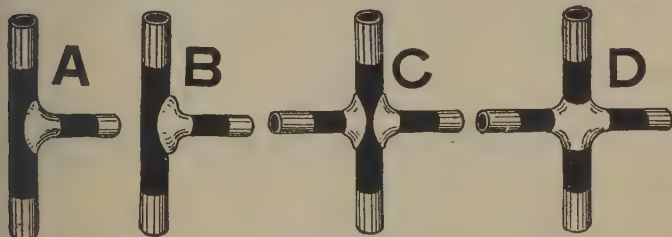
Figs. 6,410 to 6,413.—Various wiped joints. Fig. **A**, *branch joint with concave neck:* fig. **B**, *branch joint with swell neck,* this style is much more difficult to wipe than the one shown in fig. **A**; fig. **C**, *double branch cross,* this style looks well and is very easy to wipe because one branch may be wiped at a time by protecting the first with chalk or paste; fig. **D**, *regular cross joint,* more difficult than the double branch because there are four edges to take care of at one heat.

up around the outer surfaces of the two pipes.

The operations to be performed in preparing the joint for wiping consists of

1. Squaring.
2. Removing burrs.
3. Flaring female end.
4. Rasping outer edge.
5. Pointing male end.
6. Soiling
7. Marking.
8. Shaving.
9. Setting.

The tools used in performing these operations are shown in figs. 6,414 to 6,421.

To secure a good fitting joint, so that when the solder is poured it will not run inside the pipes, the ends of the pipe must first be squared by filing as in fig. 6,423.

Of course if the pipe were previously cut off perfectly true, this would be unnecessary. The skilled workman will be able to judge when the end

F̵ɪɢs. 6,414 to 6,421.—Tools used in preparing lead pipe joints for wiping.

is square "by eye," but the beginner should use a try square to test the truth of the end. When the pipe is cut, especially if a wheel cutter be used (such as shown in fig. 6,422), *burrs* will be formed on the inside and outside of the pipe.

At this stage the inside burr should be removed as in fig.

Fig. 6,422.—Wheel lead pipe cutter. Handles and frame are malleable iron, wheels of steel.
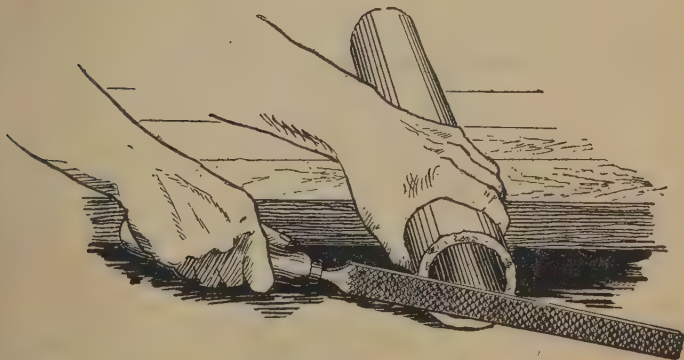
Fig. 6,423.—Preparing joint for wiping. 1. *Squaring the ends.*

6,426, using a reamer tap borer, or a shave hook as shown, the ends of both pipes being thus treated.

In the further preparation of the ends one end called the *female end* is flared or belled out with a *turn pin* fig. 6,415 or expander (fig. 6,419) so that the pipe is enlarged about a

OUTSIDE BURR

INSIDE BURR

METAL UPSET BY CRUSHING ACTION OF WHEEL CUTTER
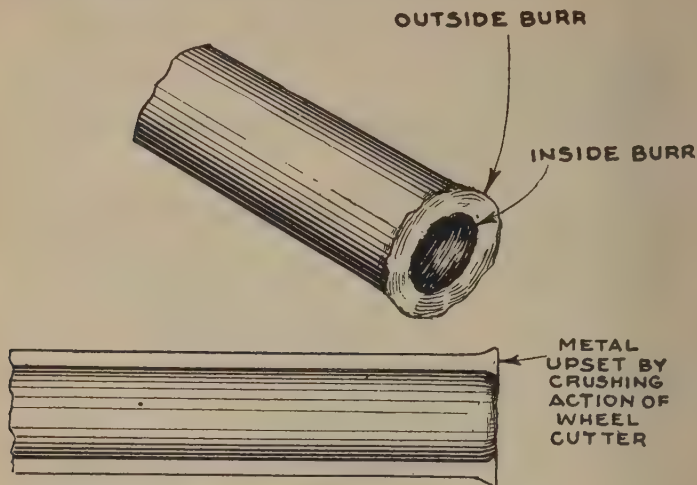
FIGS. 6,424 and 6,425.—Burr found on lead pipe when cut with a pipe cutter.

INSIDE BURR
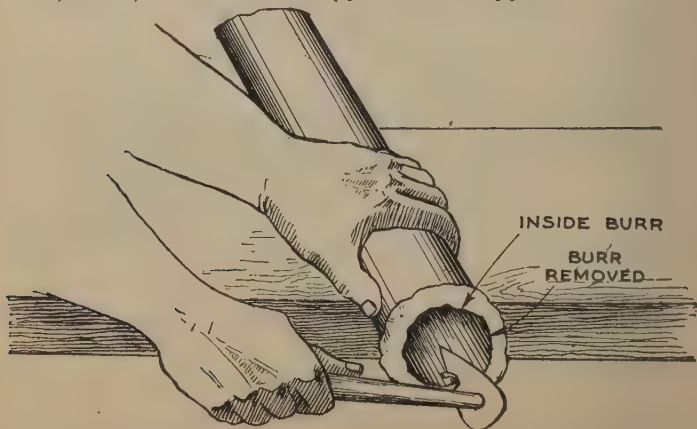
BURR REMOVED

FIGS. 6,426.—Preparing joint for wiping. 2. *Removing burr.*

quarter of an inch, the operation being shown in fig. 6,432, and shape of the finished end in fig. 6,433.

After flaring, the outer burr should be removed with a rasp,

FIGS. 6,427 to 6.431.—Various wiped joints. Fig. **E**, *angle cross,* a joint more difficult to make than the regular cross; fig. **F**, *combination branch and round joint,* sometimes made where it is most convenient to have a branch joint come at a point where two ends of the supply line must be joined; fig. **G**, *V joint,* generally used on telephone branch cables; **H**, *so-called Y joint,* usually made on lead waste pipe; fig. 1. *common flange joint.*

TURN PIN
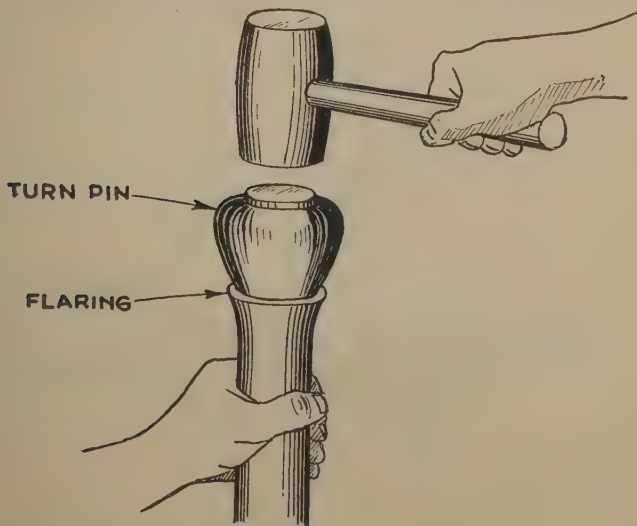
FLARING

FIG. 6,432.—Preparing joint for wiping. 3. *Flaring female end.*

holding the rasp in a plane parallel to the surface of the pipe as shown in fig. 6,437. This is done to reduce the amount of solder necessary in wiping.

The next step is to *point* the *male end* with a rasp as show in fig. 6,435.
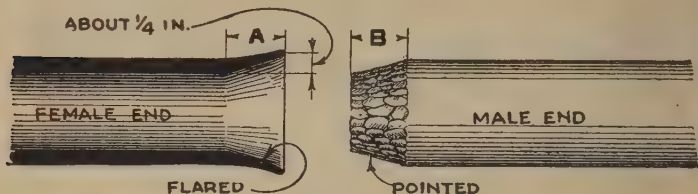
FIG. 6,433 and 6,434.—Shape of female and male ends of lead pipe for wiped joint.
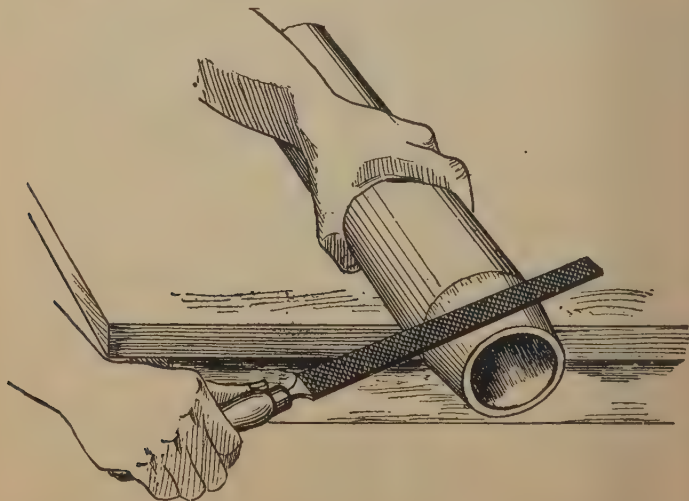
FIG. 6,435.—Preparing joint for wiping. 5. *Pointing the male end.* Make taper B longer than taper A to permit sweating.

The taper on this end should be somewhat longer than on the other end to permit sweating which is desirable as it increases the strength of the joint. This is shown in the enlarged section fig. 6,436.
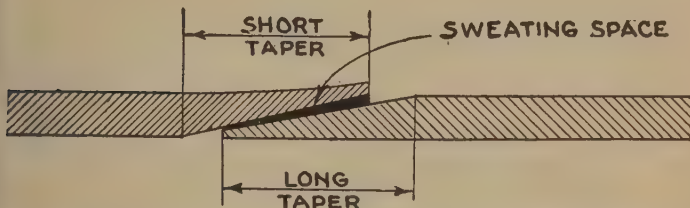
Fig. 6,436.—Enlarged section of one side of female and male ends in position showing short and long tapers forming an annular space of triangular section between the taper into which the molten solder can penetrate, being kept fluid by the external heat; this is a kind of sweating process.
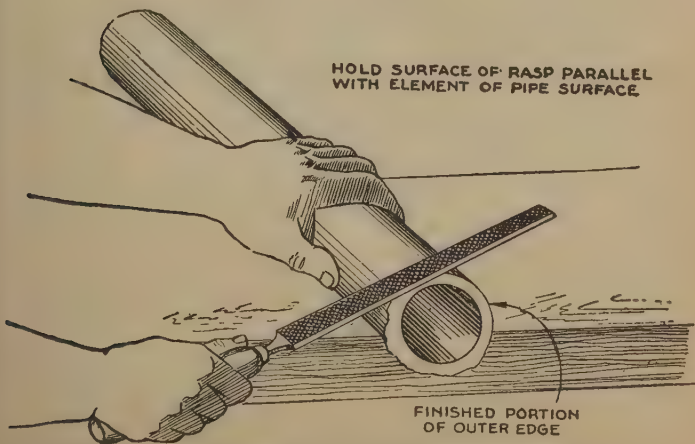
Fig. 6,437.—Preparing joint for wiping. 4. *Rasping outer edge of female end.*

In pointing, the fit of the two ends should be frequently tested until the fit shown in fig. 6,436 is approximated.

The ends are now ready for soiling.

First remove all grease or oil from the pipe by rubbing the surface with chalk, sand or wire cloth, thus presenting a clean surface to which the soil will adhere. Soil is a composition of lamp black mixed with a little glue and water;* it is painted around the pipe to prevent the adhesion of the melted solder except at its proper place, thus giving a neat and finished appearance.
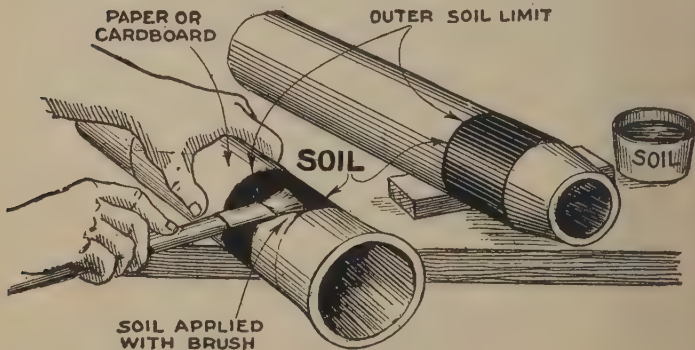
FIG. 6,438.—Preparing joint for wiping. 6. Applying the soil.

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*NOTE.—*Plumbers' Soil* may be obtained from dealers ready to mix with cold water. In the absence of the prepared article use old fashioned shoe blacking; this however is not as satisfactory as regular soil.

*NOTE.—*To make Soil:*—Take ½ oz. of pulverized glue and dissolve it in water, the gradually add a pint of dry lamp black with water enough to bring the whole to the consistency of cream. Boil and stir until the glue is thoroughly incorporated with the black. This will have to be done slowly, and when it has progressed far enough test it as follows: Paint a little of the soil on a piece of pipe and when dry, rub it smartly with your finger. If it come off easily add more glue, but if it stick and take a slight polish, it is good. If it curl off when heat is applied, there is too much glue on it, or the pipe was not cleaned previous to applying.

The entire end of each pipe is painted with the soil extending beyond the joint limit as in fig. 6,440. The neat workman will paint the outer soil limit (on both pipes) to true lines by wrapping a piece of paper on card board around the pipe with edge at desired outer soil limit as shown in fig. 6,438.

After the soil dries it must be removed from the pipe end up to the inner soil limit which governs the length of joint or distance along the pipe to which the solder will adhere.
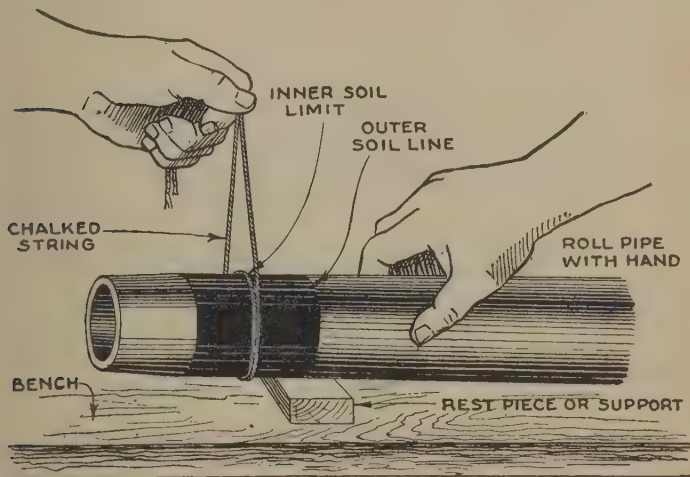
FIG. 6,439.—Preparing joint for wiping. 7. *Marking inner soil limit.*

Mark this limit (on both pipes) at the desired point with a chalked string as in fig. 6,439.

NOTE.—*The shape of the initial tapping* for branch joints varies with the size of branch and run. On supplies, the wall is thick and the bore small, so the tapping ordinarily varies little from the round. For large waste pipes of equal size the branch opening may be merely a slit with circular eyes at the ends, the whole being twice the turn up distance less the diameter of the branch pipe. —*Gray.*

NOTE.—Though there is little occasion on supply work, some plumbers are strict in opening the end of the pipe which receives the contents unless for an upright joint in which the spigot end is pointed downward regardless, in order to have the cup in the best position.—*Gray.*

The pipe ends are now ready for *shaving*. This consists of removing the soil between pipe end and inner soil limit and also the thinnest skin of lead with the shave hook as in fig. 6,440, in order to obtain a clean bright surface to which the solder will adhere.

In this operation, many plumbers, who have had enough
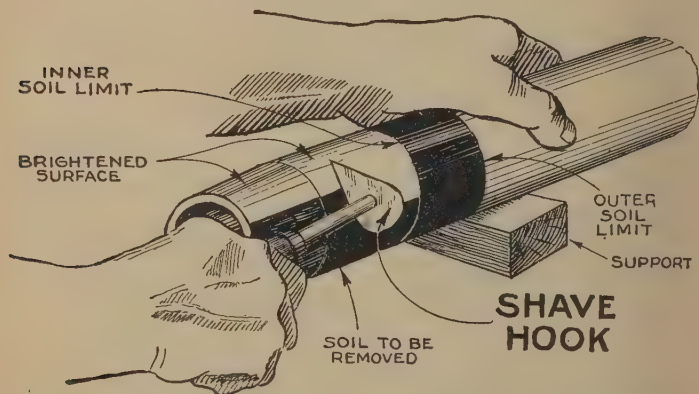
FIG. 6,440.—Preparing joint for wiping. 8. *Shaving* between pipe ends and inner soil limits.

experience to know better "butcher" the pipe ends by taking off entirely too much metal; such practice is not only a waste of time but will weaken the finished joint.

Both the internal and external surfaces must be shaved so that all the surface which should come in contact with the solder will be bright, otherwise the solder will not adhere.

Immediately after shaving, apply a little tallow to the shaved surfaces to preserve them from the oxidizing action of the atmosphere, which would otherwise tarnish the surface and form a film to which the solder cannot adhere.

The pipes are now ready for the final preparatory operation of setting.

They have the appearance, as shown in figs. 6,441 to 6,443.

Setting the pipes or fixing them rigid in position so they will
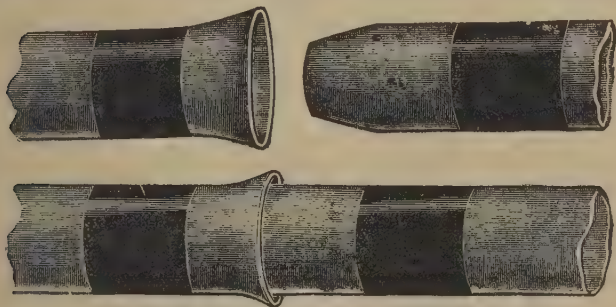
Figs. 6,441 to 6,443.—Round wiped joint; preparing the pipe ends. These ends to be united are sawed squarely across, to make the joints true with the pipe. It is usual to prepare the female end first, as shown in fig. 6,432. The end is flared or belled out with a *turn pin*, which is a taper boxwood plug, so that the pipe is enlarged a quarter of an inch. The cup thus formed serves to retain the solder. The internal and external surface must be shaved or scraped bright and clean with a *shave hook*, a small tool with a heart shaped blade set at right angles to its stem or handle. Immediately after a little tallow is applied to the parts to preserve them from the oxidizing action of the atmosphere, which would otherwise tarnish the surfaces, and form a film to which the solder cannot adhere. The male end of the pipe is tapered off with a rasp, as shown in fig. 6,435, cleaned with a shave hook and "touched" as before; the two pieces are brought together as in fig. 6,443, and are then ready for the joint.

not move during the wiping operation often taxes the ingenuity of the workman.

It is an easy job on the bench, but in a building, between beams or in other cramped places it is often very difficult to get proper support and leave room for manipulating the solder. In bench work, the pipe may be set either with blocks and string, or with clamps, being known as the *old*, and *new* methods respectively.
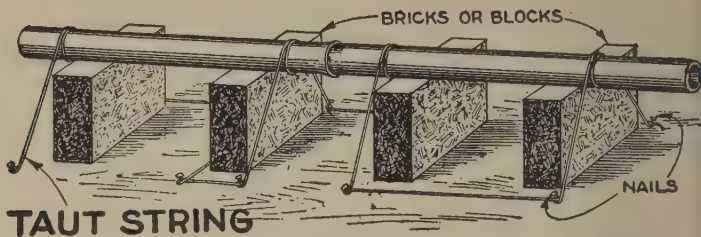
FIG. 6,444.—Preparing joint for wiping. 9. *Setting (old method)*, using blocks and nails.
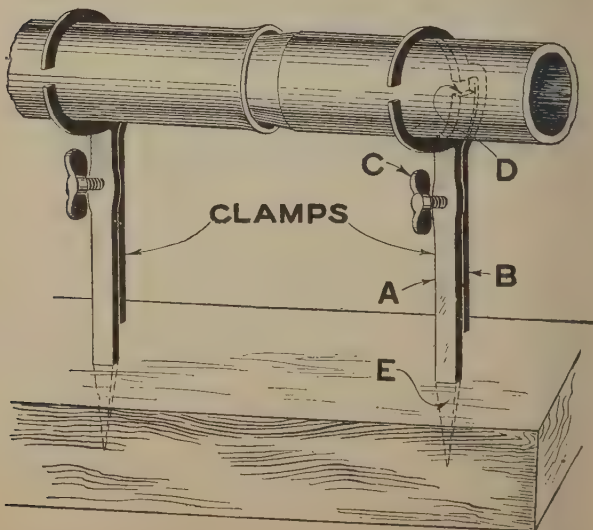
FIG. 6,445.—Preparing joint for wiping. 10. *Setting (new method)*, using clamps.

In setting by the old method, the pipes are supported on four blocks. At intermediate points on both sides of the pipe, nails are driven. A string is attached to the end nail and a turn taken around the pipe and around the opposite nail drawing the string taut; it is carried to the next nail, and the operation repeated for each pair of nails as shown in fig. 6,444.

The new method of setting makes use of clamps of which a great variety may be obtained. The clamps are fastened to the bench and one end of the pipe to be wiped placed in position in each clamp and secured by screwing up the clamp as in fig. 6,445.
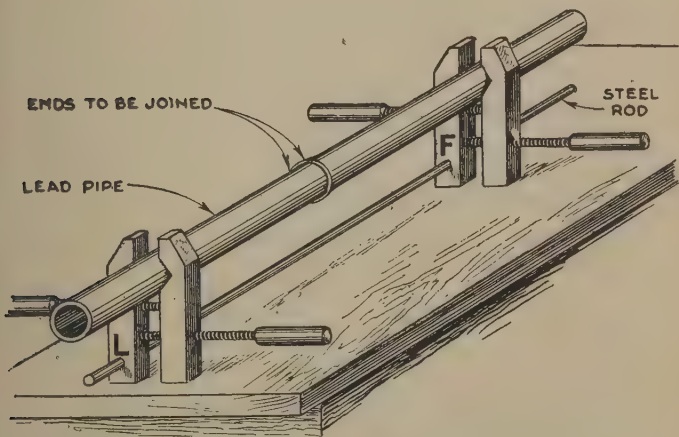
Fig. 6,446—Author's pipe clamps made of two carpenters wooden clamps, having holes L, and F, bored in one leg, accurately fitting a steel rod.

Length of Joint.—For the guidance of beginners a table giving length of joint for various size pipes is here given. The lengths specified in the table represent average American practice and will be found amply large for strength and durability, and the proportions give a pleasing appearance. The table also gives size of wiping cloth.

Lengths of Wiped Joints

(According to Hutton)

Diam. pipe in inches	One hand system		Two hand system	
	Length of joint ins.	Size of cloth ins.	Length of joint ins.	Size of cloth ins.
½	2	3×3	2¼	3×4
¾	2	3×3	2⅜	3×4
1	2	3×3	2⅜	3×4
1¼ water	2	3×3	2½	3¼×4
1¼ waste	2	3×3	2⅜	3×4
1½ water	2	3×3	2½	3¼×4
1½ waste	2	3×3	2⅜	3×4
2 waste	2	3×3	2⅜	3¼×4
3 waste	2	3×3	2½	3¼×4
4 watse	1¾	3×3 & 6×6	2¾	3¼×4 & 3¼×5
2 vertical	1¾	3×3	2	3×2½
3 vertical	1¾	3×3	2	3×2½
4 vertical	1¾	3×3	2	3×2½

Wiping the Joint.—The pipe ends having been prepared as just described and set, they are ready for the final operation of wiping. The tools needed are the furnace pot and ladle for melting and dipping out the lead, and wiping cloths. The

FIG. 6,447.—Ladle for removing solder from soldering pot and for pouring same in making wiped joints, etc.
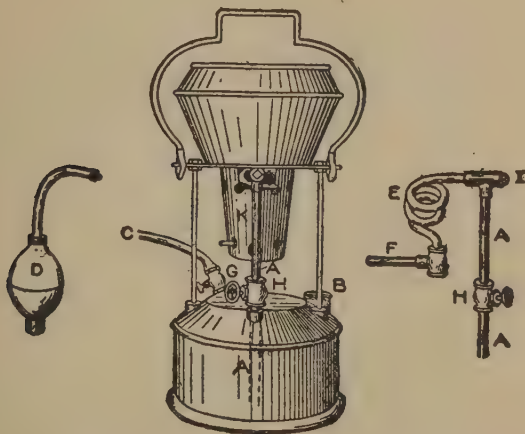
FIGS. 6,448 to 6,450.—Plumber's gasoline furnace, adapted to heating soldering pots and copper bolts. *In construction*, the gasoline supply for the blast passes through AA, and is provided with valve H and clean out plug I. The lower end of the supply extends nearly to the bottom of the reservoir. The gasoline passes through coil E, which is partially filled with wire, usually a scrap of small wire cable, to prevent flame running back into the reservoir. The fuel issues from a single small hole at F, which is turned so that the flame will impinge on the coil. Air pressure on top of the gasoline in the reservoir is necessary to make a blast. The air cock is shown at G. For ordinary purposes sufficient pressure can be obtained by blowing air in the hose at C with the lungs, but for a short blast, a bulb containing check valves, shown at D, is used to increase the pressure. The filling plug is at B. *To light the furnace,* valve H is opened and some of the gasoline allowed to play on the coil, from which it falls back into the bottom of cup K. Admit about two tablespoonfuls to cup, close H, and light the gasoline through one of the holes in K. When coil is sufficiently heated, gas instead of liquid will come from the end F, forming a blast which increases in intensity as E becomes hotter. The strength of the blast is regulated by valve H. One pumping keeps the furnace in working order until the lowering of the gasoline level has provided so much room that the pressure of the expanded air is not sufficient to maintain the blast; it then becomes necessary to pump in more air, or to replenish the gasoline and again establish the pressure.

following table gives the amount of solder required for wiping joints of various sizes of pipe:

Solder Required for Wiped Joints

(According to Hutton)

Size of pipe ins.......	½	¾	1	1¼	1¼ water	1½ waste
Ounces of Solder......	9	12	16	16	18	18

Size of pipe ins.	1½ water	2 waste	3 waste	4 waste	4 vertical
Ozs. of Solder	20	20	24	34	28

For joints up to 2 ins. diameter a pot containing 10 lbs. of solder will be found large enough ordinarily.

There are three methods of wiping:

1. One hand.
2. Two hand.
3. Rolling method.

On making a joint by the one hand method, a quantity of solder is taken from the pot by means of the ladle, the solder being previously heated so hot that the hand can be kept within two inches of its surface. The solder is poured lightly on the joint, the ladle being moved backward and forward, so that too much solder is not put in one place. The solder is also poured an inch or two on the soiling, to make the pipe of proper temperature. Naturally the further the heat is run or taken along the pipe, the better the chance of making the joint. The operator keeps pouring and with the left hand holds the cloth to catch the solder, and also to cause the same to tin the lower side of the pipe, and to keep the solder from dropping down. By the process of steady pouring, the solder now becomes nice and soft and begins to feel shaped, firm and bulky.

When in this shape and in a semi-fluid condition the ladle is put down, and, with the left hand, the operation of wiping, as illustrated, is begun, working from the soiling towards the top of the bulb. If the lead cool rapidly, it is reheated to a plastic condition by a torch, or a heated iron. When the joint is completed, it is cooled with a water spray, so that the lead shall not have time to alter its shape.

The *cloth* used for wiping is a pad of moleskin or fustian about four inches square made from a piece twelve inches by nine, folded six times and sewed to keep it from opening; the side next the pipe is saturated with hot tallow when used. If the lead has been brought to the heat of the solder, and the latter properly manipulated and shaped while in a semi-fluid or plastic condition, the joint gradually assumes the finished egg shaped appearance.

FIG. 6,451.—Soldering pot.
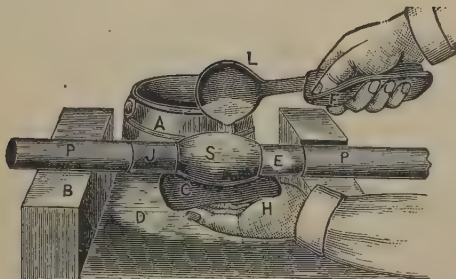
FIG. 6,452.—Wiping a horizontal joint; one hand method. A, melting pot; B, brick support; C, cloth; D, waste solder; E, J, soil; S, solder; H, hand; PP, pipe end to be joined.

In wiping a vertical joint a small piece of cardboard cut open is placed under the joint to catch excess solder as shown

NOTE.—Both moleskin and ticking cloths require to be *broke in*, before they will be satisfactory; that is, the surface must be treated so that the solder will not adhere to it. Soak the cloths in melted tallow, press out the excess and rub with powdered chalk or talcum.

FIG. 6,453.—Wiping a vertical joint; *one hand method.*
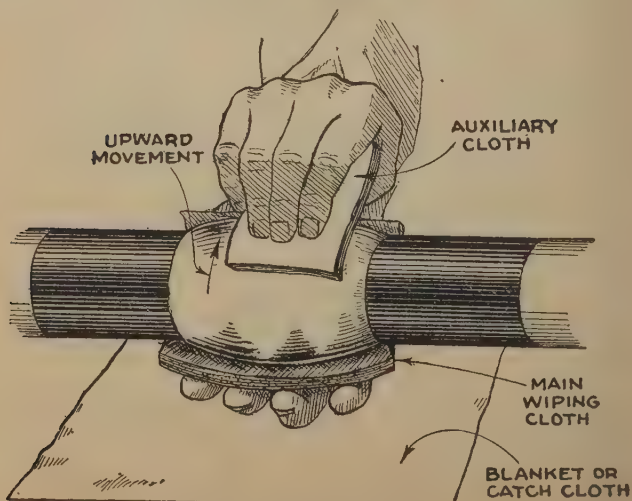
FIG. 6,454.—Wiping a horizontal joint; *two hand method.*

in fig. 6,453, forming a flange held in place around the pipe by twine.

In wiping by the two hand method, as soon as there is a sufficient body of solder around the pipe to retain the heat long enough for the wiping operation, drop the ladle and pick up a small cloth known as the auxiliary cloth. This is held in the right hand and the wiping cloth in the left hand.

The metal is brought to the top of the joint by a movement of both hands as shown in fig. 6,454. Hold the main cloth under the joint and with the
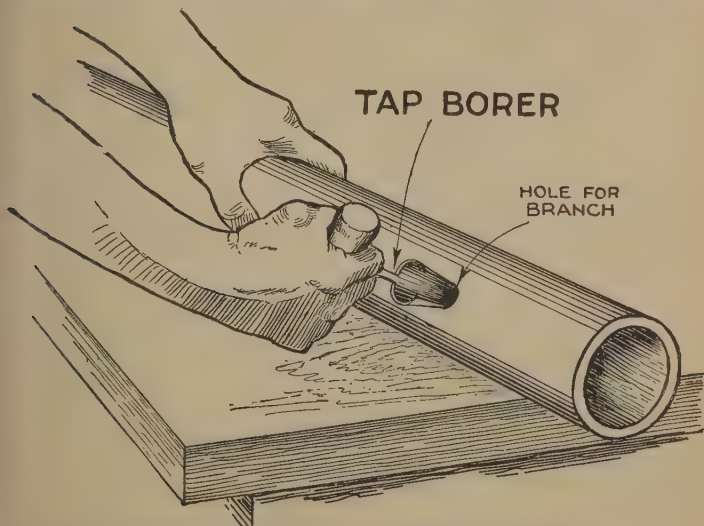
Fig. 6,455.—Preparing branch joint for wiping. 1. *Boring hole* with tap borer.

auxiliary cloth wipe off surplus solder from each and roughly mould what is left on top to the shape of the joint, throwing all the hot solder into the wiping cloth. Stock this surplus solder to bottom of joint and roughly mould to proper shape. Drop auxiliary cloth and finish joint to shape with the main cloth, using both hands.

Wiping a Branch Joint.—Usually more skill is required in

preparing and wiping a branch joint than a regular run around joint. The operations of preparing the joint for wiping are:

1. Boring.
2. Expanding.
3. Flaring out.
4. Removing burrs.
5. Soiling.

EXPANDER

ENLARGING HOLE BY UPSETTING
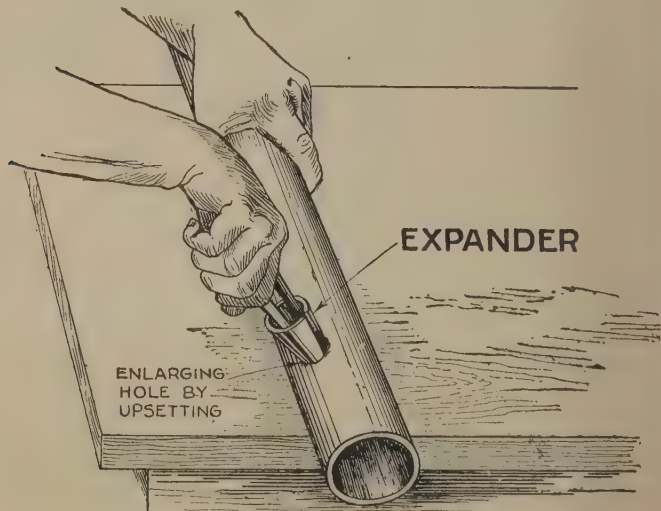
Fig. 6,456.—Preparing pipe for branch joint. 2. *Expanding* with expander.

6. Shaving.
7. Setting.

First the pipe from which a branch is to run is tapped with a tap borer as in fig. 6,455.

In using a tap borer do not insert far enough for its point to come into contact with the opposite side of the pipe. For ½ to 1 in. water pipe, bore

hole to ⅝ in. diam.; if for waste pipe, make hole larger proportional to the size of the pipe.

Next the metal around this hole is upset and flared out using an expander and bending pin as shown in figs. 6,456 and 6,457.

The shape of the opening is plainly shown in fig. 6,458.
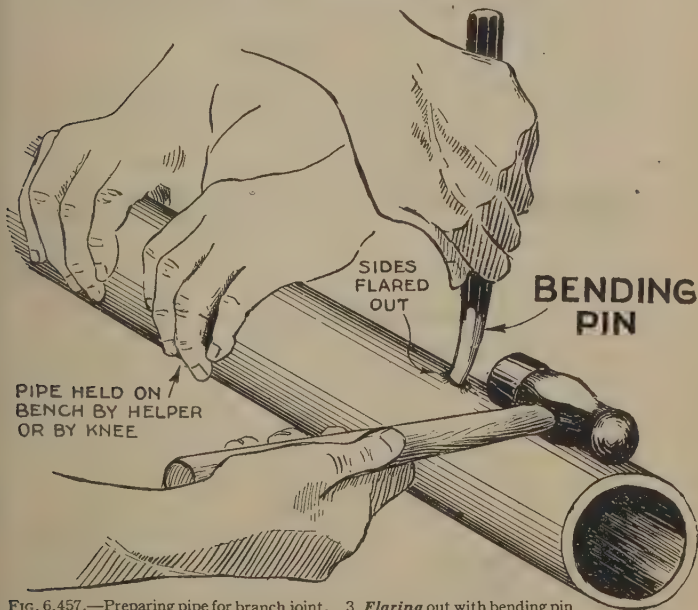
FIG. 6,457.—Preparing pipe for branch joint. 3. *Flaring* out with bending pin

The operations following consist of removing burrs, soiling, marking off, shaving and setting which are performed in a way similar to these described for plain or running joints.

In setting, the parts should be secured firmly in position with clamps, or blocks, etc.

It will be found easier to wipe the joint by setting up the branch in the vertical position.

In wiping, pour on far and near sides as shown in figs. 6,459 and 6,460 holding the cloth at an angle which will distribute the solder over the area to be covered.
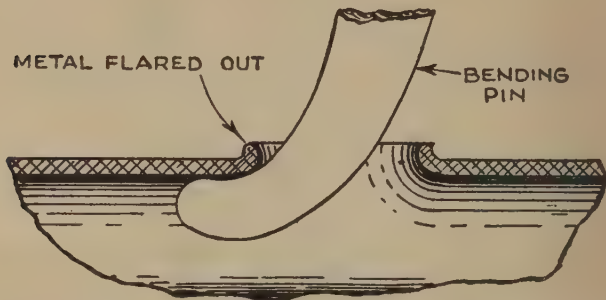
FIG. 6,458.—Sectional view of pipe with bending pin in position showing shape of flared opening formed by the use of this tool.
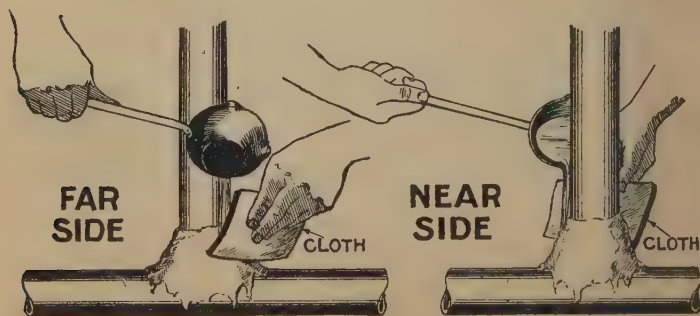
FIGS. 6,459 and 6,460.—Pouring vertical joint on far and near sides.
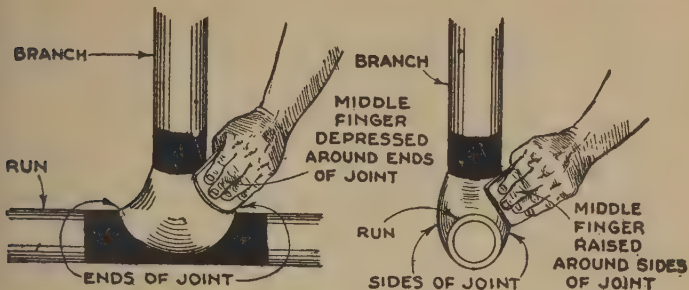
Figs. 6,461 and 6,462.—Movements in wiping vertical branch joint. 1. Note middle finger depressed in wiping around ends (fig. 6,461), and middle finger raised in wiping around sides (fig. 6,462.)
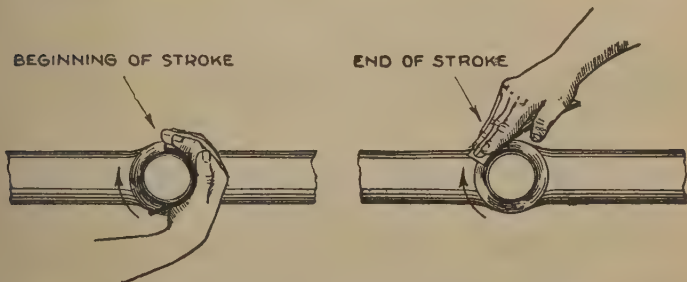
Figs. 6,463 and 6,464.—Movements in wiping vertical branch joint. 2. Encircling the branch with one stroke.

NOTE.—*Types of joint.* The cloth and copper bit have made most of the plumber's joints in the past and will continue to do so, though sweated joints on certain service are none the less efficient and will be oftener pressed into service in the future wherever their peculiar fitness is not circumscribed by some unusual conditions. There is a lively prejudice against any but wiped joints on the part of many who have mistaken the cause of the usually good and lengthy service of the wiped variety, attributing the merit solely to the mode of making. The fact that a joint is wiped and of the usual dimensions is not conclusive evidence of merit. A safe joint can be wiped much smaller than the general run of joints, but not to compare in size with the weight of solder capable of equal service when compacted to the utmost as given by a flowing heat. The ease of wiping, porosity, probable imperfect laps, butting masses too cold to properly weld, uncertainty of perfect tinning, etc. all combined make it advisable to stick to the dimensions under which the wipe joint has preserved its reputation.—*Gray.*

As the solder begins to flow it is kept worked up by manipulating the cloth. When sufficient solder has been poured to form the joint, the plumber first puts it roughly to shape with the cloth, followed by the wiping movements.

The first wiping stroke encircles the branch, the solder being shaped by depressing the middle finger as the cloth is being brought around the ends of the joint, gradually raising this finger as it comes on the sides parallel to the run. These operations are shown in figs. 6,461 and 6,462. The stroke should begin on the near side as far around as possible so the operator can entirely encircle the branch with one stroke as shown in the plan.
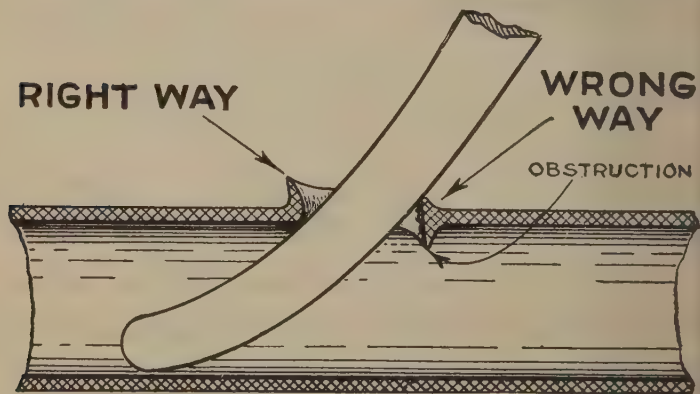
Fig. 6,365.—Right and wrong formation with bending pin in flaring for branch joint.

CHAPTER 110

Lead Work

3. Bending

The bending of lead pipe, especially pipes of large diameter requires skill and a knowledge of the changes which take place in the metal during the bending process.
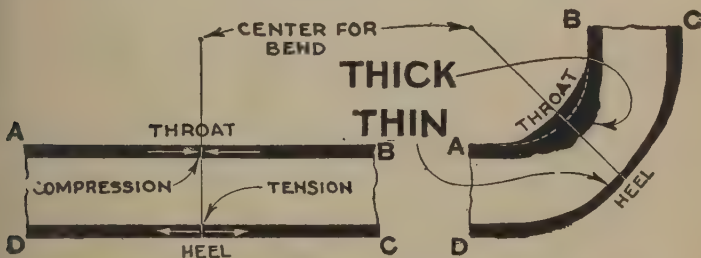
FIGS. 6,466 and 6,467.—Length of lead pipe *before* and *after* bending showing changes in wall thickness at throat and heel due to the compression and tension stresses set up in bending.

When a pipe is bent the metal is subjected to stresses which produce compression along the inner wall or that part of the pipe nearest the center of the curve to which the pipe is being bent, called the *throat*, and which also produces tension in the outer wall, called the *heel*, as shown in fig. 6,466. These stresses cause the metal of the pipe to become thicker at the throat and thinner at the heel as shown in fig. 6,467.

Sometimes instead of the metal "piling up," or becoming thicker at the throat it will buckle along this inner side as shown in fig. 6,468. The reason for these distortions of the metal is illustrated in figs. 6,469 to 6,471.

Disregarding the thickness of the walls in fig. 6,469 let ABCD, represent a piece of 4 inch pipe bent 90° to an inside radius AO, of 3 ins. Accordingly throat AB, will be an arc of a 6 inch circle, and heel DC, arc of a 14 inch circle, hence (using table of circles)
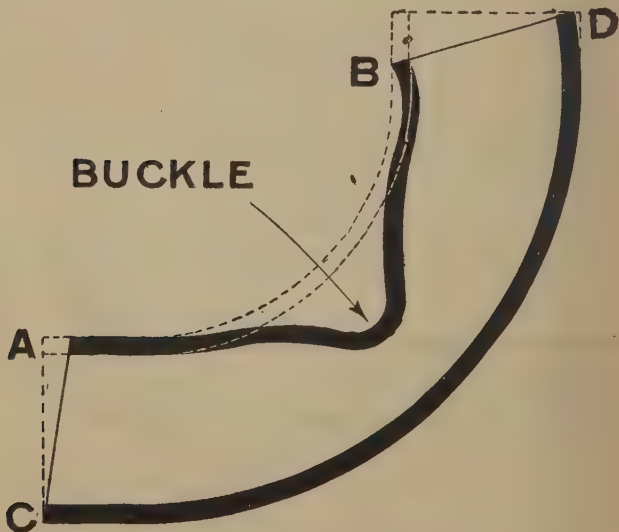
FIG. 6,468.—Buckle in throat due to bending.

length arc AB=¼ of 18.85=4.71 ins.
length arc DC=¼ of 43.98=11 ins.

also considering an arc MS, through the center of the pipe, its radius is 3+2=5 ins. accordingly.

length arc MS=¼ of 31.42=7.86.

In the bending of the pipe the metal along this arc that is at the distance MO (fig. 6,470) from the center of the bend is not disturbed, so
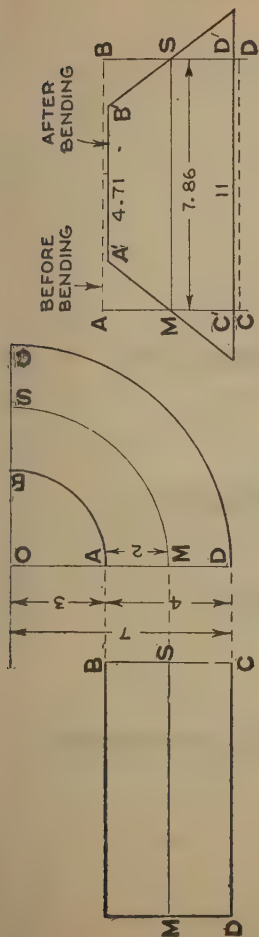
FIGS. 6,469 to 6,471.—Diagram illustrating change in length L along throat and heel of 1 ipe due to bending.

that the length of MS (fig. 6,469) before bending, is the same as MS (fig. 6,470) after bending.

Further, in bending, the metal in arcs between MS, and the throat AB, is shortened by *compression* and the metal in arcs between MS, and the heel DC, is lengthened by *tension*. Accordingly, if the bend shown in fig. 6,470, were straightened out without changing the length of the throat and heel and ends AC and BD, it would assume the shape A'B'D'C' shown in fig. 6,471, its original shape before bending being here shown on dotted lines ABDC for comparison. Note here that A'B', is considerably shorter than AB, and C'D', considerably larger than CD. From this it is clearly seen the enormous stresses set up in the metal of a pipe in bending and the resulting distortion. Considering thickness, suppose the metal be ¼ in. thick before bending as in fig. 6,472, then

area of ABMS= ¼ × 7.86 = 1.97 sq. ins.

and since the metal has not been distorted by bending, ABMS and DCLF have equal areas. Now in bending, as shown in fig. 6,471, length of throat was reduced to 4.71 ins., and length of heel increased to 11 ins., thickness of of metal in throat or (as in fig. 6,473).

TT'= 1.97 ÷ 4.71 = .42 in.

Similarly, thickness of metal in heel, or

HH'= 1.97 ÷ 11 = .18 ins.

The changes or deformations due to bending are better compared in the tabulation following:

	Before bending	After bending	Change in %
Thickness TT' throat	.25 in.	.42 in.	168% increase
Thickness HH' heel	.25 in.	.18 in.	72% decrease
Difference in thickness	O'	.24 in.	
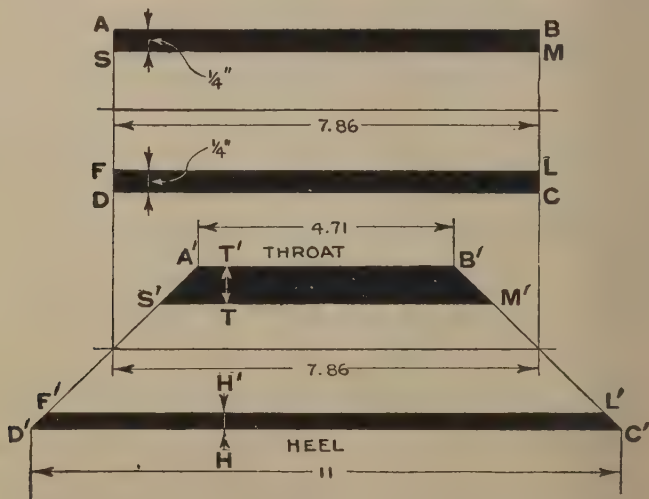
Figs. 6,472 and 6,473.—Comparison showing changes in thickness of metal in pipe along throat and heel due to stresses set up in bending.

From the tabulation it is seen how great is the deformation or changes in sectional area of the metal at throat and heel resulting from the enormous stresses to which the metal is subjected in bending. Of course, in actual

bending the change in thickness would not be uniform at different parts of the throat or heel but would vary depending upon the quality of the metal at the various points.

In order to avoid the thinning or drawing out of the metal along the heel in bending, the metal along the throat should first be heated to soften it and so reduce the compression stress

KEEP THROAT
HOT
TO SOFTEN THE
METAL AND REDUCE
COMPRESSION
STRESS

THROAT

HEEL

KEEP HEEL
COLD
FOR MAXIMUM TENSILE
STRENGTH TO RESIST
TENSILE STRESS AND
AVOID DECREASE IN
THICKNESS OF METAL
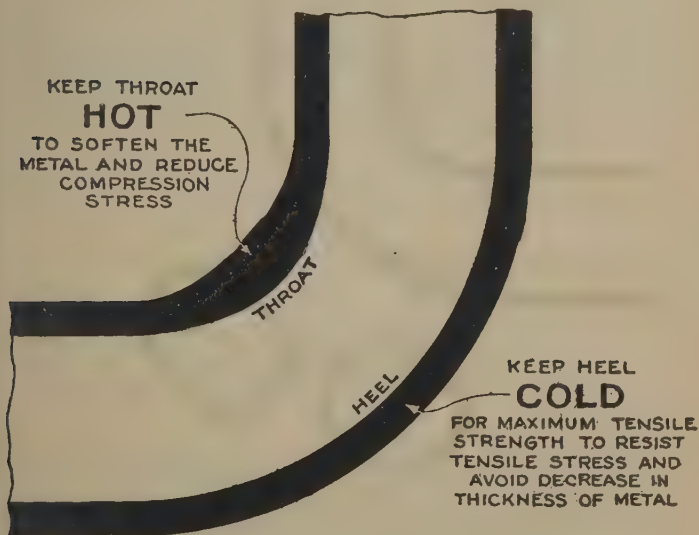
FIG. 6,474.—Desirable temperature conditions at throat and heel in bending to avoid thinning or drawing out of the metal in heel, with its resulting decrease in strength of pipe.

necessary to upset it in bending; also, the metal along the heel should be kept cold to preserve maximum tensile strength, so that it will resist the tensile stress it receives in bending

instead of being drawn out and thinned. These conditions are shown in fig. 6,474.

Heating the throat before bending not only preserves the strength of heel wall but tends to reduce the flattening, a pipe receives in bending. This flattening is due to the effect of the compression and tensile stresses in throat and heel respectively which tends to force the throat and heel together as shown in fig. 6,475.

Many plumbers will not bother to make a proper bend on a small pipe
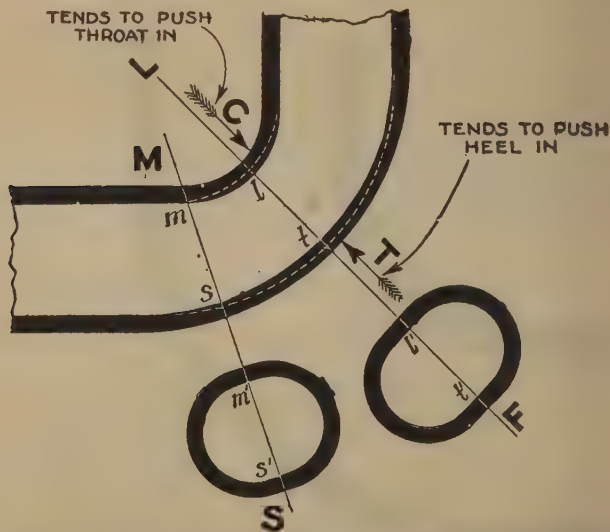
FIG. 6,475.—Diagram showing that the bending forces of compression along the throat, and of tension along the heel tend to flatten the pipe as indicated in the cross sections on **MS** and **LF**. The arrows marked **C** and **T**, indicate the *resultant forces* of compression and tension acting normally to the throat and heel respectively, set up by the stresses introduced in the metal in bending. As clearly seen by the sections on **MS** and **LF**, they tend to cause the pipe to collapse, diameter *lf* being less than *ms*, thus the sectional area of the pipe is reduced by flattening, choking the flow.

by heating but bend it in place with resulting flattening which chokes the flow. Numerous examples of this neglect can be seen in almost any plumbing installation. Since lead is a very soft metal it rarely happens that

lead pipes are received in perfect condition. In shipping, the pipes often get flattened or dented and all these defects should be removed before bending.

The easiest method of removing dents and flat places is by heating with a dummy. Two forms of dummy are shown in figs. 6,476 and 6,477, and the operation of beating out a dent, in fig. 6,478. Dents and flats may also be removed by driving a drift plug through the pipe. Two forms of
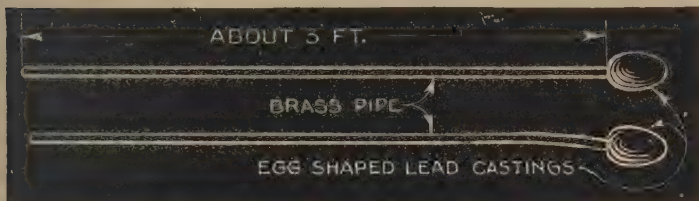
FIGS. 6,476 and 6,477.—Straight and curved dummies for beating dent and flats out of lead pipe. One tool may serve for both forms by bending the pipe to any desired curve.
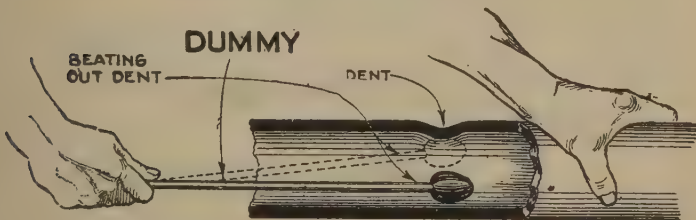
FIG. 6,478.—Removing dent (or flat) by beating inside of pipe with dummy.

FIGS. 6,479 and 6,480.—Bernz short and long pattern drift plugs, made in sizes up to 2 ins., of dogwood, boxwood, or lignum vitae.

drift plugs are shown in fig. 6,479 and 6,480 and the method of using in removing dent in fig. 6,481.

This method is satisfactory for a small dent but in case of a large one which projects considerably, a bobbin or series of bobbins should be used.

The difference between a drift plug and a bobbin is shown in figs. 6,482 and 6,483. The operation of removing a large dent progressively by using a series of bobbins of graduated sizes is shown in figs. 6,486 to 6,489.

Bending Methods.—After the dents and flats have been taken out of a pipe, as instructed in the preceding section, it
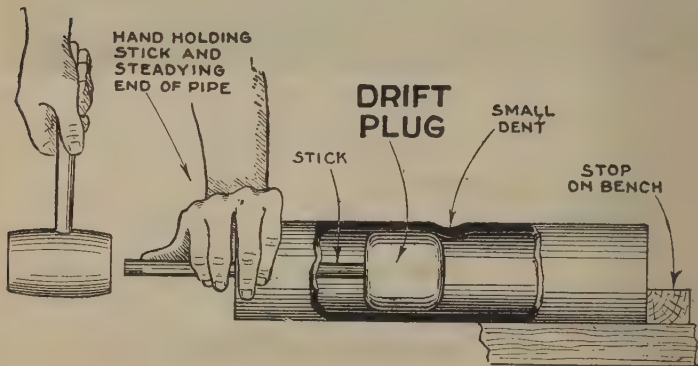
Fig. 6,481.—Application of drift plug in removing small dent in lead pipe.
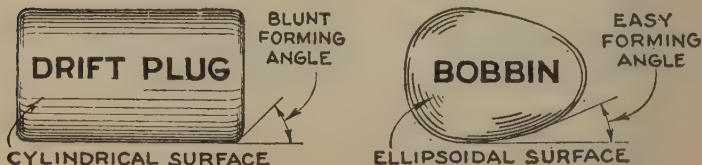
Figs. 6,482 and 6,483.—Comparison of drift plug and bobbin.
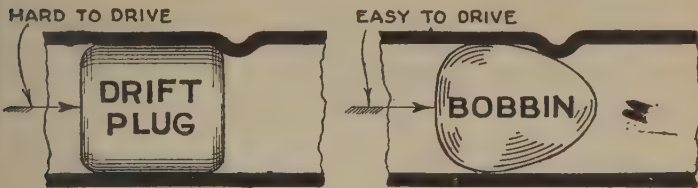
FIGS. 6,484 and 6,485.—Application of drift plug and bobbin in removing *large* dent, showing why bobbin is preferable to drift plug.
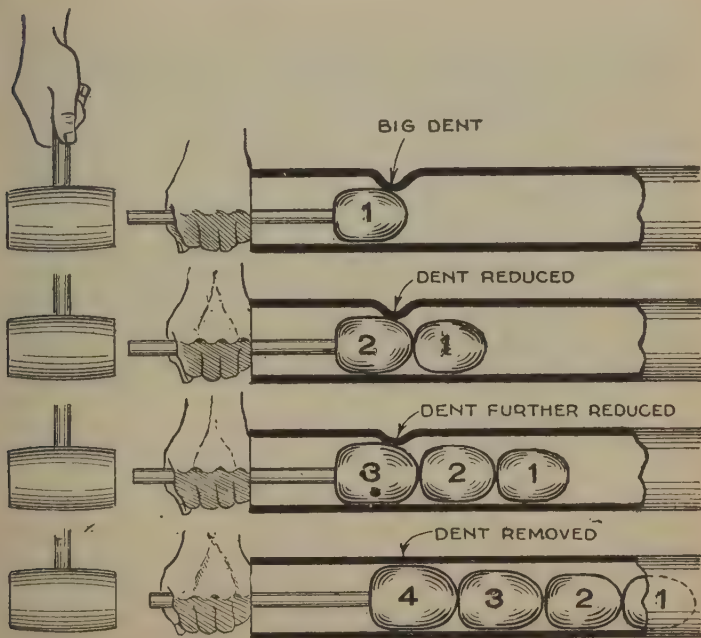
FIGS. 6,486 to 6,489.—Removal of large dent in lead pipe by passing through the pipe a series of bobbins of graduated sizes.

is in condition for bending. There are numerous methods of bending lead pipe, and these may be classified:

1. With respect to the temperature at which the metal is worked, as:

     a. Cold.
     b. Hot.

2. With respect to the mode of preventing deformations, as by
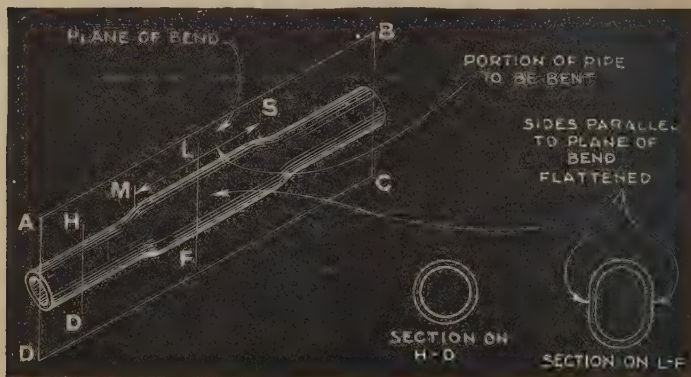
Figs. 6,490 to 6,492.—Preparation of pipe for cold bending by slightly flattening the side parallel to the plane of bending. This is an imaginary plane (ACBD) passed through the pipe to show which surfaces of the pipe are to be flattened relative to the direction of the bend. MS, is the portion of pipe to be bent. Section on HD, shows normal circular shape of pipe, and section on LF, its flattened shape along the portion to be bent.

     a. Internal wall support $\begin{cases} \text{sand} \\ \text{springs} \end{cases}$

3. With respect to the mode of correcting deformations, as by

     a. Internal forces $\begin{cases} \text{bobbins} \\ \text{bobbins and followers} \end{cases}$
     b. Internal and external dressing.
     c. Cutting and beating.

Bending Cold and Hot.—If a small pipe is to be bent cold, the sides (parallel to the plane of the bend) should be slightly flattened, which will tend to prevent flattening during the bending process, the pipe while being bent returning to its circular cross sectional form. Of course, if the pipe be bent to too small a radius, final flattening will result reducing the capacity of the pipe.
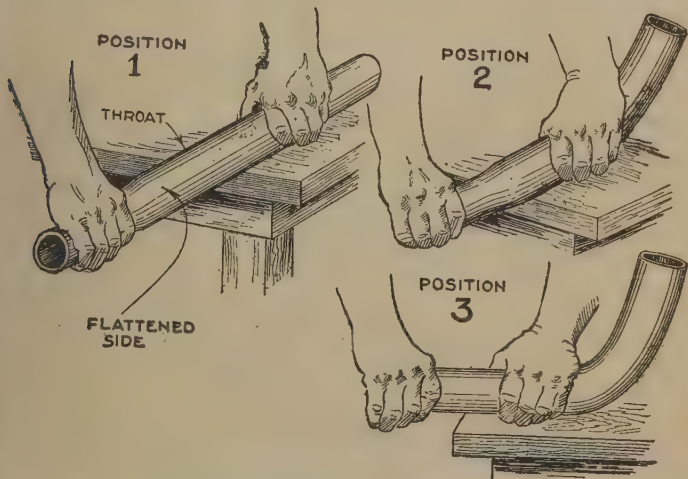
FIGS. 6,493 to 6,495.—Cold bending by progressively moving the hand along the portion being bent as indicated by positions 1 to 3.

Figs. 6,490 to 6,492 illustrate the flattening of pipe previous to bending, and figs. 6,493 to 6,495 bending by hand; note that as the bend progresses, the hand is progressively moved along the bend (positions **1** to **3**).

A machine for bending is shown in figs. 6,496 and 6,497.

When small pipes are bent cold they usually become thicker in the throat and thinner in the heel, and although the circular

cross form be retained on the outside surface in bending cold in a machine, the inside walls would be distended because of the uneven thickness of the metal. The thinning of the metal in the heel (and resulting weakening of the pipe) may be avoided by heating the throat before bending, as has already been explained.
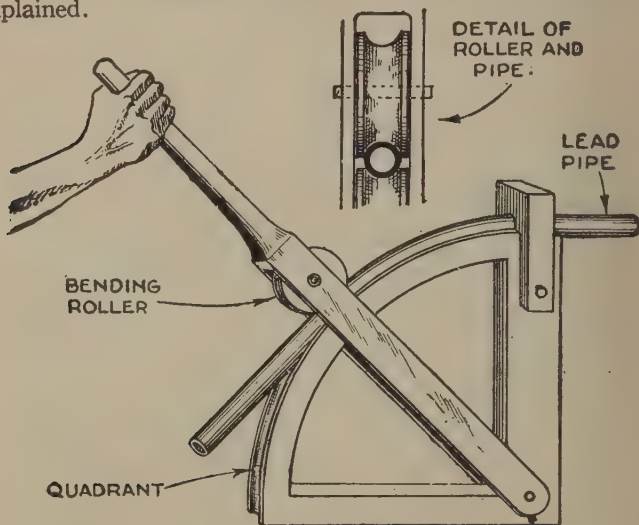
FIGS. 6,496 and 6,497.—Cold bending with lever bending machine. Since the contour of the grooved bending roller and grooved quadrant (over which the roller passes) accurately conforms to the circular sectional shape of the pipe, no flattening before bending is necessary to prevent distortion as the metal is held to its shape by the confining roller and groove in quadrant.

FIG. 6,498.—Bernz lead dresser. It is made in dogwood, boxwood or lignum vitae weighing respectively 11, 12, or 13 lbs. The dresser measures 13¼ ins. over all, 8 in. face and 1¾ ins. wide.

Bending with Internal Wall Supports.—To prevent the flattening of lead pipe in bending, sometimes the internal surface of the pipe is held to its original shape by internal supports or incompressible material such as

1. Sand.
2. Spring.
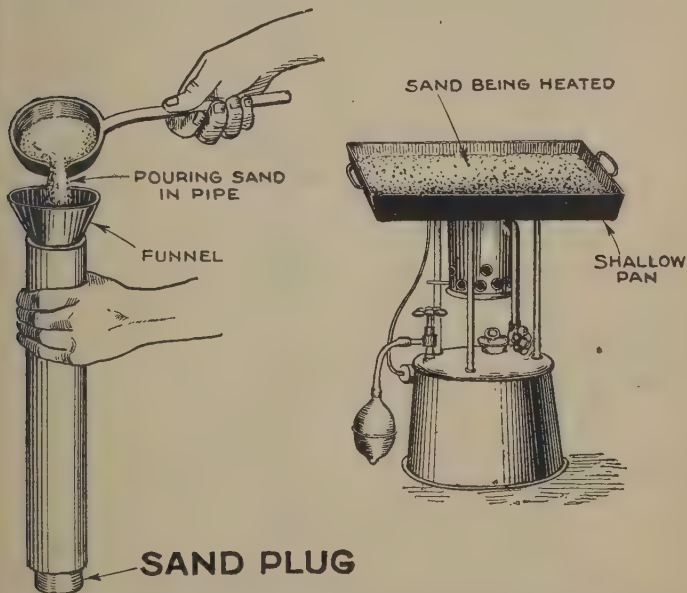
FIGS. 6,499 and 6,500.—*Bending with sand, 1.* Operations of filling pipe with sand preparatory to bending and method of warming the sand by placing in a shallow pan over a gasoline furnace or other source of heat. The hot sand is conveniently poured into the pipe by using a ladle and funnel, the sand being heated as in fig. 6,500.

3. Rubber rod.

In the first instance a quantity of sand (sufficient to fill the pipe) is dried by heating, so that it will pack to a firm mass,

One end of the pipe is closed with a sand plug and the heated sand then poured in as in figs. 6,499 and 6,500.

During this operation the pipe is kept in motion to shake down the sand. When the pipe is apparently full of sand, it should be tapped with the dresser as in fig. 6,501 which will cause the sand to settle down as in fig. 6,502 so that a little more sand can be added as in fig. 6,503. The end should then be closed by inserting a sand plug or beating over.

BEFORE   **AFTER**

SAND LEVEL

ADDING MORE SAND
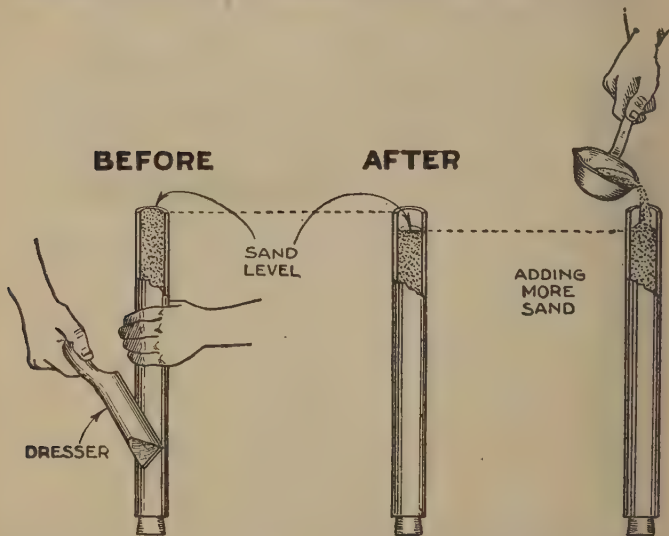
DRESSER

Figs. 6,501 to 6,503.—*Bending with sand, 2.* Tapping pipe with dresser after filling so that sand will settle and permit maximum amount of sand to be placed in pipe.

If the beating over of the pipe end be employed to close the pipe, a wad of paper should be inserted before beating over to prevent loss of sand.

The pipe is now bent by manipulating it as shown in fig. 6,504, the firmly packed sand inside the pipe holding out the walls pretty much to shape.

2ND OPERATION
PUSH FORWARD AND DOWN

1ST OPERATION
EASY OVER ANGLE BEND

SHARP
BEND

FIG. 6,504—*Bending with sand, 3.*
Making a sharp bend by first, over
bending to easy curve (as indicated
by dotted lines); and then bringing
back and sharpening to required angle.

BENDING OVER
THE KNEE

FIG. 6,505.—Method of bending by pulling pipe across
the knee; a commonly employed but objectionable
method.

If a sharp bend be desired carry an easy bend around past the angle desired, then sharpen up the angle by bending back on the heel as shown in fig. 6,504 2nd operation.

An expert plumber can usually make a good bend by bending over the knee as shown in fig. 6,505, but this is not a good method as the pressure on the pipe is not so well distributed resulting in greater distortion of the metal.

After the pipe has been bent to shape any uneven parts
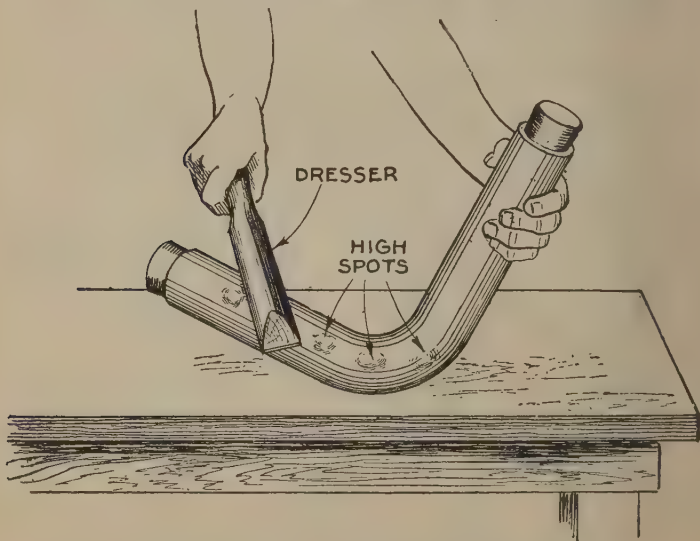
Fig. 6,506.—*Bending with sand, 4.* Dressing down high spots with dresser.

should be corrected by dressing with the dresser as in fig. 6,506.

The sand method of bending is desirable for pipes up to 2 ins. Larger sizes, are made better by the method of internal forcers. or by internal and external dressing, as with

Figs. 6,507 and 6,508.—Bernz pipe bending springs. Fig. 6,507, plain pattern; fig. 6,508, iron pipe connection pattern; with this connection the spring may be screwed to a ½ in. iron pipe and threaded any distance through a lead pipe.

Fig. 6,509.—*Bending with spring, 1.* Bending spring in position inside the pipe forming an internal wall support which holds walls of pipe to shape in bending.
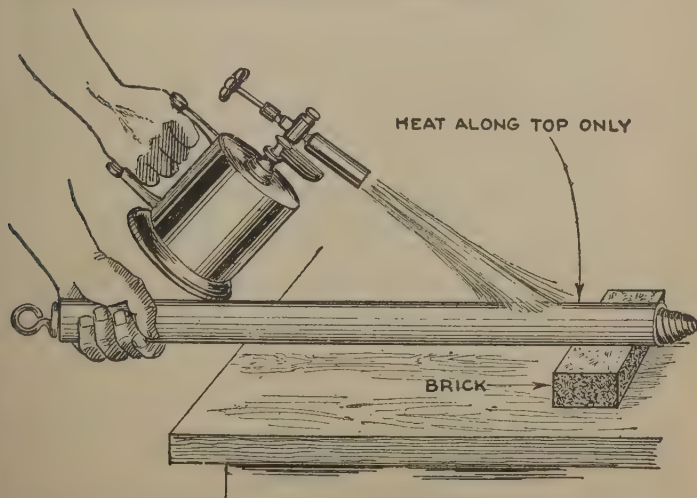
Fig. 6,510.—*Bending with spring, 2.* Heating the pipe on throat side to counteract the distortion in metal due to stresses in bending.

these methods the original thickness of the pipe is retained. Instead of sand support, a spring may be used.

The type spring suitable is shown in figs. 6,507 and 6,508, and its application in fig. 6,509. In inserting the spring, turn it in the direction in which it is wound as this reduces the diameter of the convolutions making it easier to insert. If the spring be too snug a fit, it should be rubbed with tallow before inserting. Since spring bending is used for small size pipes (1 to 2 in. diameter) and the walls are thicker in proportion than in the larger sizes, there is more distortion (thinning and thickening of the metal

CLOTH OR PAPER
PROTECTION FOR HAND
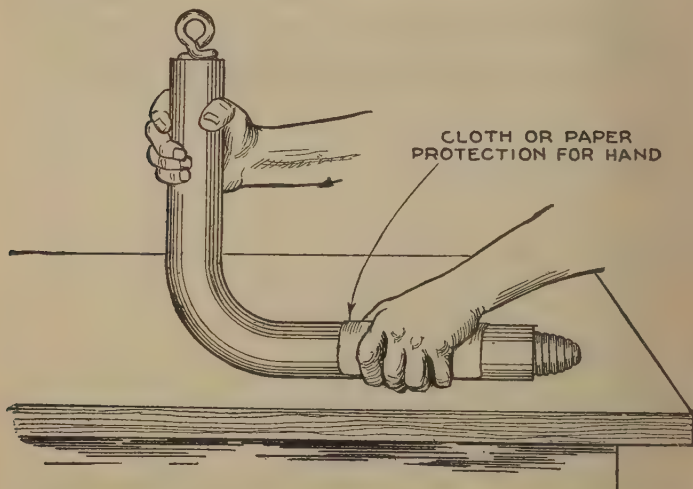
Fɪɢ. 6,511.—*Bending with spring, 3.* Bending with hands, using cloth or paper protection from the heat.

in heel and throat respectively) and to counteract this it is desirable to heat the pipe along one side previous to bending, the pipe being bent so that the heated part will form the throat.

Fig. 6,510 shows the method of heating with ordinary gasoline torch. In heating care should be taken not to over heat otherwise the temper of

the spring would be destroyed or the pipe damaged. The pipe is bent in the usual way moving the hand along the bend during the operation, but since the pipe has been heated a cloth or wad of paper will be necessary to protect the hand from the heat as shown in fig. 6,511.

Sometimes the equivalent of a spring or solid rubber rod is used although this is as a rule too soft.
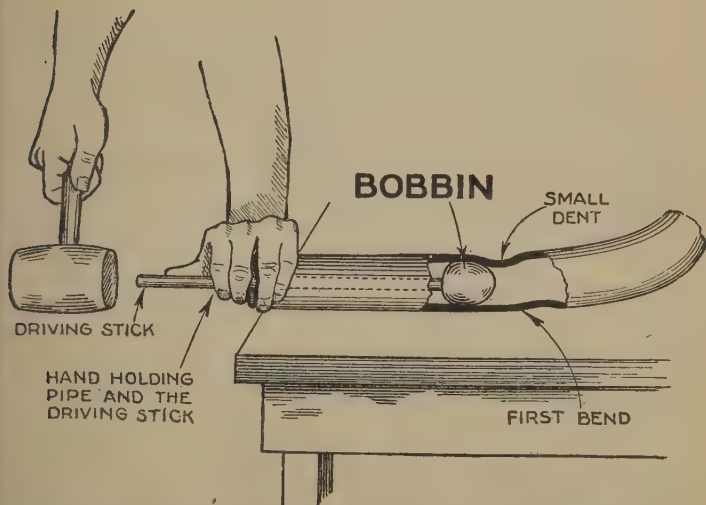
FIG. 6,512.—*Bending with bobbins, 1.* First bend showing removal of throat distortion by driving through a bobbin.

Bending with Internal Forcers.—The term *internal forcers* is here used to indicate devices which are placed inside the pipe and which snugly fit the interior walls. When pushed or pulled through the pipe, any dent or flat spot of the wall is forced back to its correct position by a wedge like action.

Two types of internal forcers are the drift plug and the bobbin shown in figs. 6,482 and 6,483.

In the preliminary truing up of the pipe before bending, a drift plug may be used as in fig. 6,481, if the pipe be in fairly good shape, but if there be any big dents, a bobbin should be used as in fig. 6,485, and in extreme cases a series of bobbins of graduated sizes progressively applied as in fig. 6,486 to 6,489.
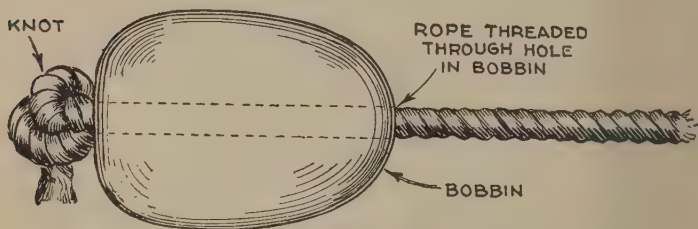
FIG. 6,513.—Method of attaching bobbin to rope for pulling through pipe.
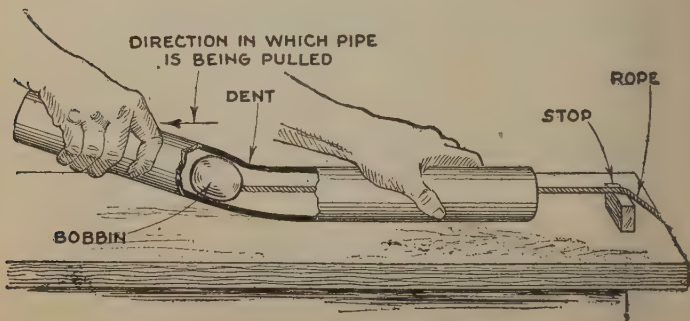
FIG. 6,514.—*Bending with bobbins, 2.* Pulling bobbin through pipe.

The difference in the action of a drift plug and a bobbin is very plainly illustrated in figs. 6,482 to 6,483.

The pipe having been trued up, it is ready for bending.

First make a very slight bend by hand. The small indentation in the throat due to this first bend may be removed by driving through a bobbin with a drive stick as shown in fig. 6,512. The pipe is now bent a few more degrees and since the curve is too great to permit driving the bobbin with a stick, the bobbin is attached to a small rope as shown in fig. 6,513 and pulled through the pipe by fastening the other end of the rope to some stationary object and pulling the pipe as shown in fig. 6,514.

These operations are repeated for as many successive bendings as are necessary to bring the pipe to the desired curve.

In case of a deep dent or buckle, the aid of a dummy as shown in figs. 6,515 and 6,516 preparatory to passing through the bobbin will help.

Figs. 6,515 and 6,516.—*Bending with bobbins, 3.* Internal dressing of deep dent with dummy preparatory to its removal with bobbin.

Another method of removing a deep dent or buckle is by passing through a series of graduated bobbins either by driving as shown in fig. 6,486 to 6,489 or by threading them on a rope and pulling as in fig. 6,517.

In pulling, a series of sharp jerky pulls should be made, holding the pipe so as to support the bend at the throat. At various stages, the dresser is useful in smoothing out small irregularities of surface as shown in fig. 6,518.
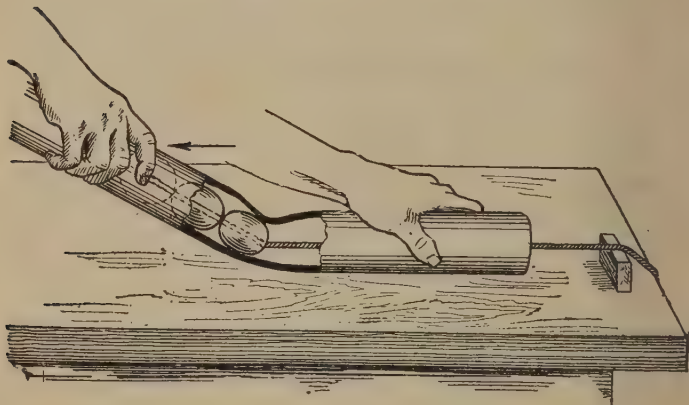
Fɪɢ. 6,517.—*Bending with bobbins, 3.* Removal of deep dent by pulling through a string of bobbins of graduated sizes.

A method sometimes employed in making a compound bend such as an S bend using *followers* for driving the bobbin is shown in fig. 6,519.

If the followers be too long they will get jammed in a short bend as in fig. 6,523, and if too short they turned or angled as in fig. 6,524. Sometimes a bobbin will split. The bobbin method of bending is well adapted to pipes of from 2 to 3 ins. diameter.

NOTE.—*The difference in shape* between a follower and a drift plug should be carefully noted as shown in figs. 6,520 and 6,521.
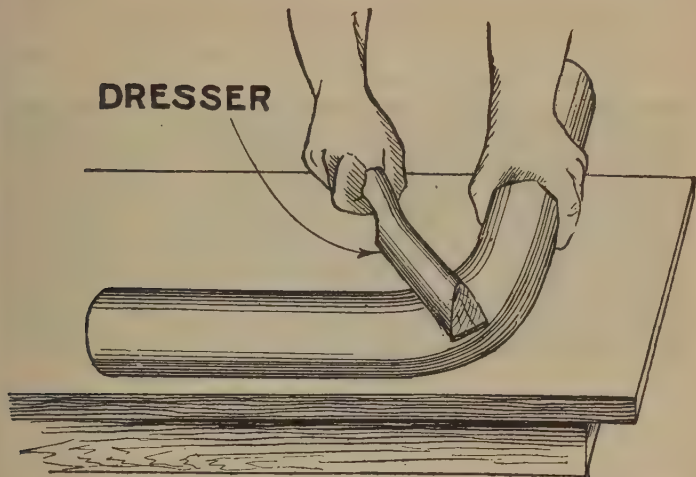
FIG. 6,518.—*Bending with bobbins, 4.* Application of dresser to smooth out irregularities of surface.
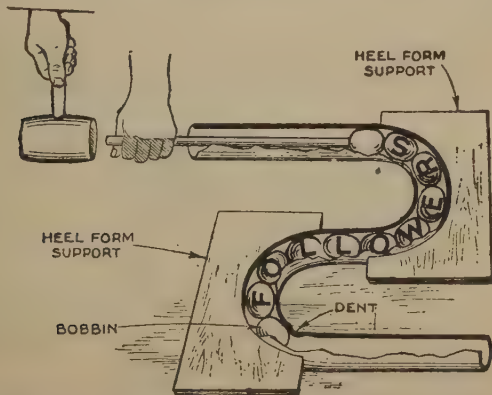
FIG. 6,519.—*Bending with bobbin and followers,* a difficult yet sometimes used method in bending pipe to compound curves such as an S bend for a trap.

Bending by Internal and External Dressing.—For pipes larger than 3 ins., bends are made with a dummy because there
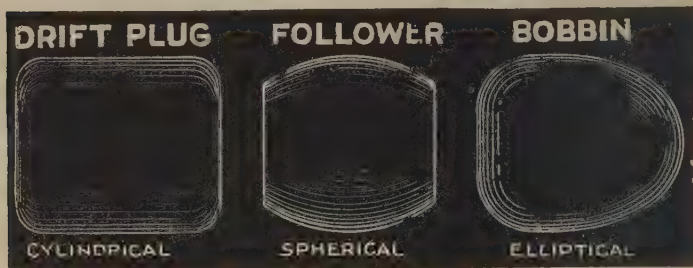
FIGS. 6,520 to 6,522.—Comparison of drift plug, follower and bobbin; note carefully difference in shape between a drift plug and a follower.
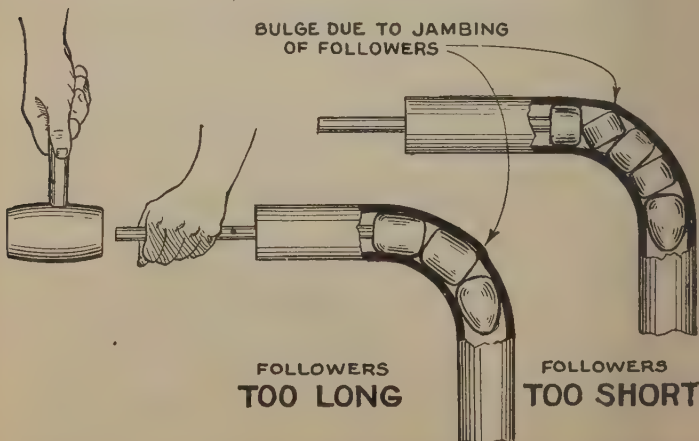
FIGS. 6,523 and 6,524.—*Bending with bobbin and followers;* jambing of followers when too long or too short for the curve.

is sufficient internal space for a stroke long enough to give effective blows.
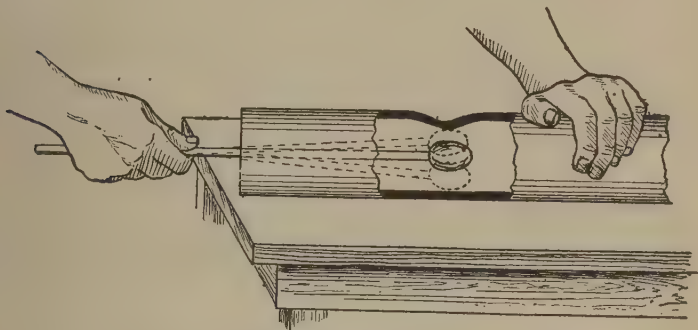
FIG. .6,525—*Bending with dummy and dresser, 1.* Truing up pipe preliminary to bending.

CLOTH TO PROTECT
HAND FROM HEAT

FIG. 6,526.—*Bending with dummy and dresser, 2.* First bending.

Before beginning to bend the pipe, any dents and flat places are removed with the dummy as in fig. 6,525.

The pipe is now heated along the side that is to be the throat of the bend, with a torch same as shown in fig. 6,510, and the pipe bent a few degrees as shown in fig. 6,526.

This will cause more or less of a dent in the throat and bulges midway between throat and heel, shown exaggerated in fig. 6,527.
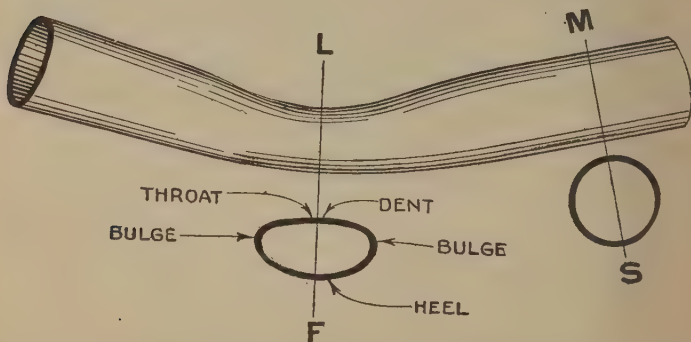
FIG. 6,527.--*Bending with dummy and dresser, 3.* Distortions caused by bending; dent at throat and bulges in sides midway between throat and heel; **MS**, shows normal section and **LF**, distortions due to bending.

The dent is removed by using the dummy (straight pattern) in the same way as shown in fig. 6,525.

The bulges midway between throat and heel are beaten back to shape with the dresser as shown in fig. 6,528. These bulges are dressed, not inward, but toward the heel in order to maintain the correct thickness of metal there.

An expert will give the dresser an oblique motion which tends to equalize the thickness of metal building up the heel and thinning the throat.
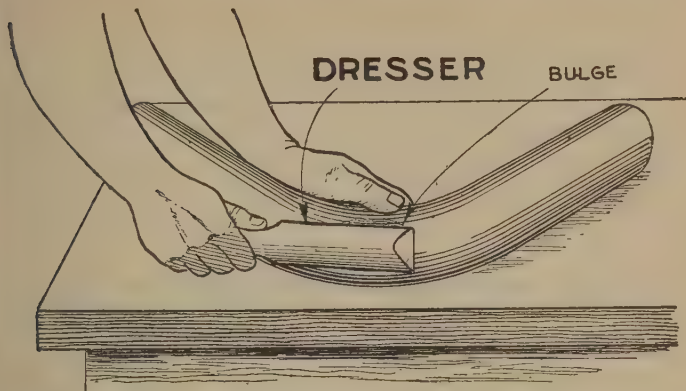
FIG. 6,528.—*Bending with dummy and dresser, 4.* Beating bulges back into place with dresser.

FIG. 6,529.—*Bending with dummy and dresser, 5.* Final dressing with sheet lead dresser,

The sharpness of the bend is increased by successive bend-ings until the desired curve is obtained, using the dummy and dresser after each bending to remove the distortions.

When the pipe has received several bendings, the distortion at throat cannot be reached by a straight dummy owing to the sharpness of the curve. At this stage the handle of the dummy is curved to conform with the curve of the pipe and used by the *fulcrum method*, similarly as shown in figs. 6,515 and 6,516.
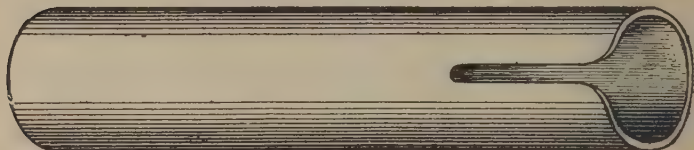
FIG. 6,530.—*Bending by cutting and beating, 1.* Shape of V notch cut out of pipe. The corners are rounded off with a rasp.
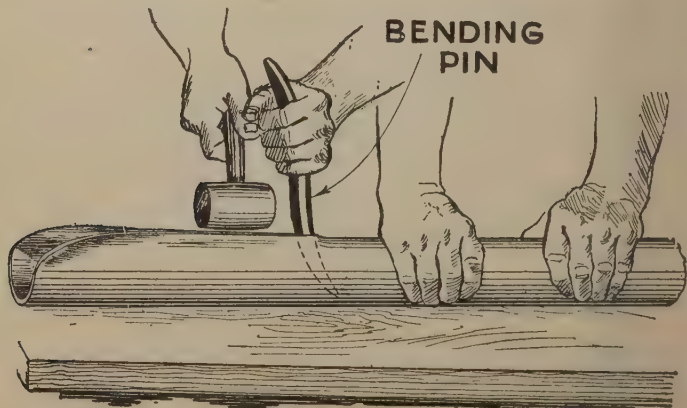
FIG. 6,531.—*Bending by cutting and beating, 2.* Raising end of V with bending pin.

For the final dressing a piece of sheet lead about 3×10 ins. is used as a dresser, it is roughly bent to form a handle by which it is held, being used as shown in fig. 6,529.

Bending by Cutting and Beating.—When a very sharp bend is required (sometimes called short heel bend) it is best done
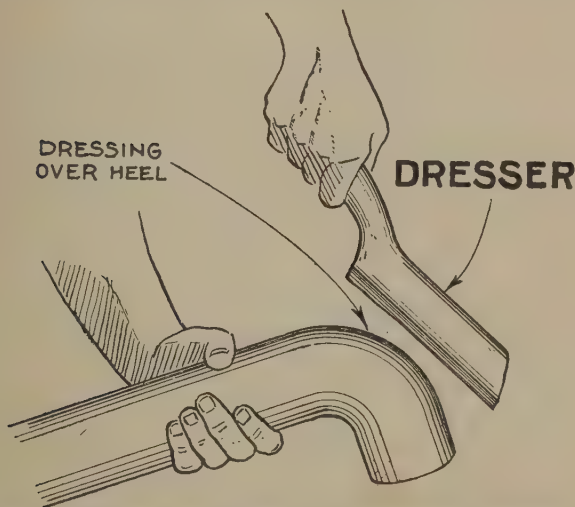
FIG. 6,532.—*Bending by cutting and beating, 3.* Dressing over heel with dresser.

by cutting away some of the metal to avoid too much distortion.

First tap a small hole in the pipe with the tap borer, and cut a V-notch down to the hole so that the part cut out will have the shape (and proportions to size of pipe) as shown in fig. 6,530.

Run up the end of the V with a bending pin as shown in fig. 6,531 and then dress over the heel as shown in fig. 6,532.

The seam is closed either by wiping or by soldering.

CHAPTER 111

Lead Work

4. Beating

The plumber should have some knowledge of the methods employed in *beating* sheet lead to various shapes, as in roofing work; covering sink and drain boards, etc. The various examples of beating operations in this Chapter will give an insight into this particular phase of lead work.
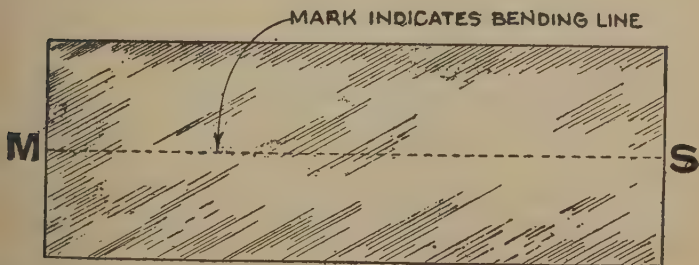
Fig. 6,533.—*Beating lead flashing, 1.* Sheet marked for bending to form upstand.

Beating Lead Flashing.—Lead is a very desirable material for flashings especially where the shape is more or less complicated, as for instance, a flashing around a circular bay window. By its use, instead of copper or tin, considerable cutting,
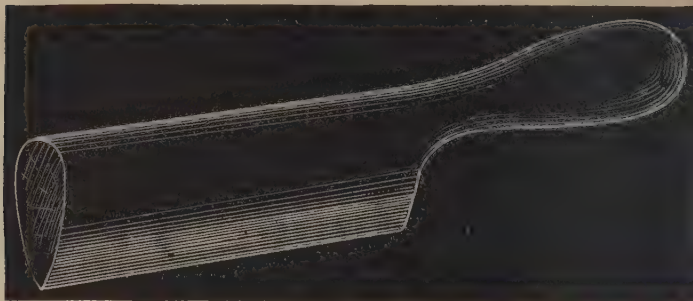
FIG. 6,534.—V shape dresser used to increase the sharpness of the bend.
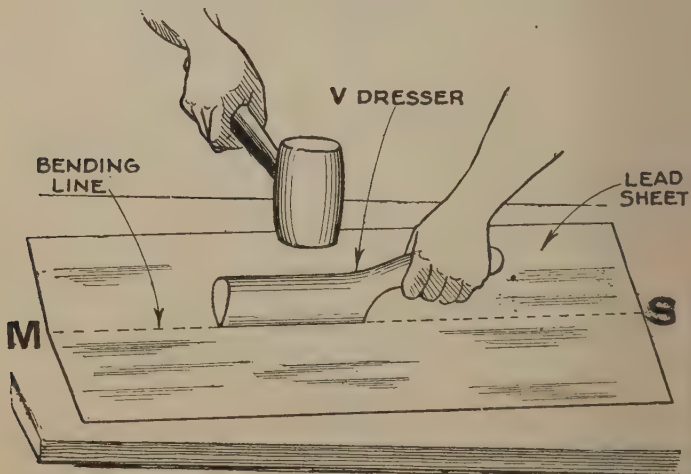
FIG. 6,535.—*Beating lead flashing, 2.* Indenting bending line MS, to secure sharp bend for upstand.

fitting and resulting soldered joints are avoided, reducing the risk of leakage.

In beating a flashing for the window just mentioned, the first operation is to secure what is called an *upstand* on the flashing.

The lead is marked where it is to be turned up to form the upstand at MS in fig. 6,533.

In bending the lead, the sharpness of the bend is increased by means
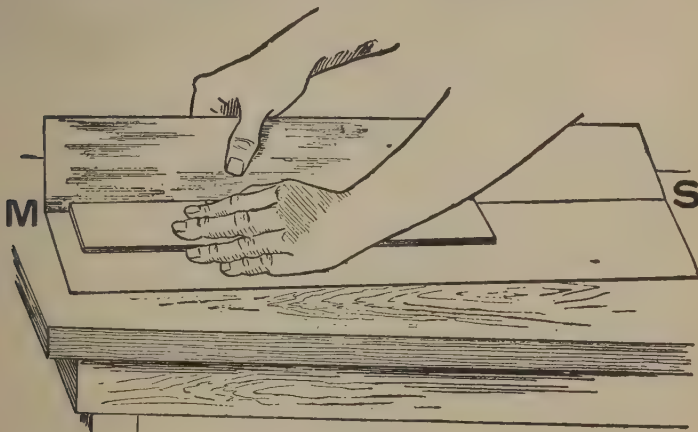
FIG. 6,536.—*Beating lead flashing, 3.* Bending up lead along MS.

of a V shaped dresser, as shown in fig. 6,534, and applied in fig. 6,535. The lead is next bent up sharply along the line MS, as shown in fig. 6,536

The difficulty presented in making the flashing is the beating operations necessary to shape the lead to the circular form of the window.

It must be evident from fig. 6,538 that certain parts of the lead must be stretched while other parts must be compressed. That is, the parts farthest
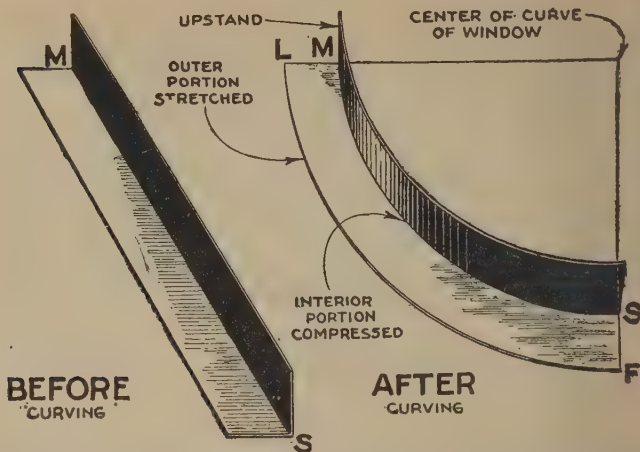
FIGS. 6,537 and 6,538.—*Beating lead flashing, 4.* Shape of the lead *before* and *after* curving showing that sections remote from the center of curvature must be stretched and those near the center must be compressed. This must be evident from fig. 6,538, because since arc LF, is remote from the center of curve, it is longer than arc MS, near the center of curve.
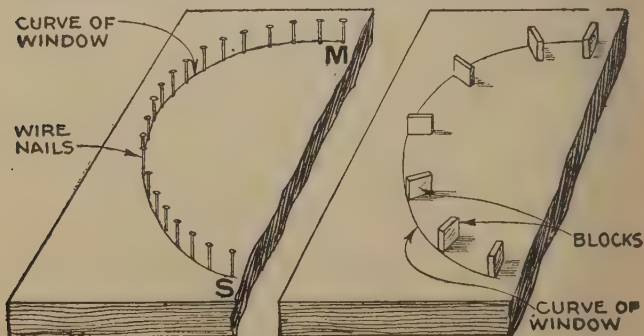
FIG. 6,539 and 6,540.—*Beating lead flashing, 5.* Making a bending form on bench by driving in wire nails (fig. 6,539), or nailing blocks on the bench to the curve SM, previously described to same radius as curve of window (fig. 6,540).

from the center of the curve must occupy more space than those nearest the center of the curve, hence the former must be stretched out and the latter compressed as the illustration shows. Figs. 6,537 and 6,538 show shape of the lead before and after curving to fit the window.

On the bench, describe an arc of same radius as the curve of the window and drive partly down a series of wire nails as in fig. 6,539, or preferably blocks as in fig. 6,540 to serve as a
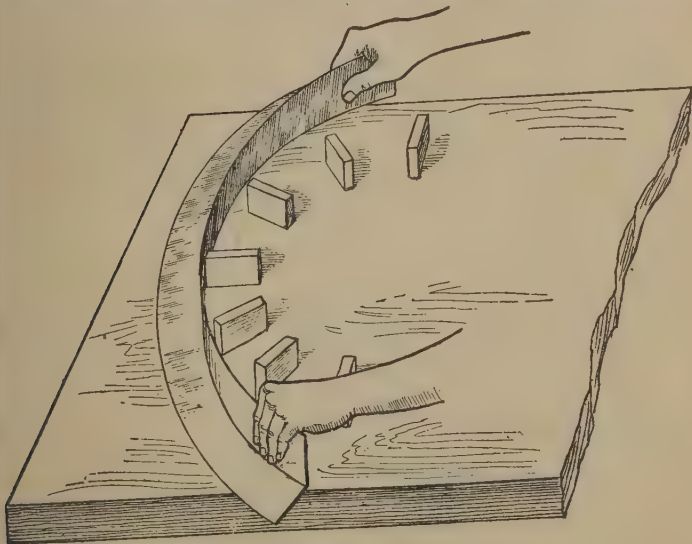
Fig. 6,541.—*Beating lead flashing, 6.* Making first bend over form.

form for bending the lead to the curve of the window.

Now place the lead on the form and bend it slightly as in fig. 6,541.

In this operation, because of the stresses set up tending to lengthen the outer edge LF, and shorten the line MS, of the angle formed by the upstand and horizontal parts, the lead will assume same shape as in fig. 6,542.

The horizontal side must be expanded by beating as in fig. 6,543 so as to lengthen LF, and cause it to lie flat or in position in dotted line L'F', fig. 6,542.

In beating the lead with the dresser start beating at the outer edge moving dresser progressively toward the center of curve as indicated by the arrow in fig. 6,543 so as to thin out the lead along the outer portion *m*,
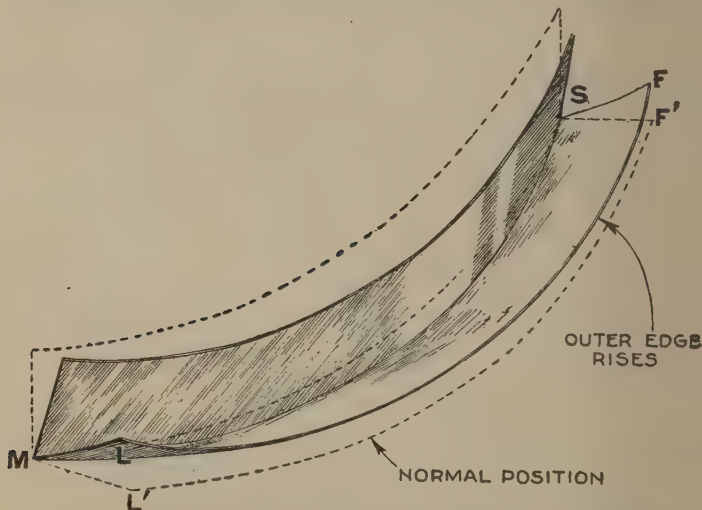
FIG. 6,542.—*Beating lead flashing,* 7. Shape of lead after making first bend over form. Note that the horizontal edge LF, turns up instead of lying flat as shown by the dotted line L'F'.

expanding this part, and compressing it toward the inner part *s*, remembering that arc LF, should be expanded and arc MS, compressed to bring the side of the flashing to its normal horizontal position.

The alternate operations of bending over form and beating just described should be repeated a sufficient number of times to bring the lead to the desired form shown in fig. 6,538.
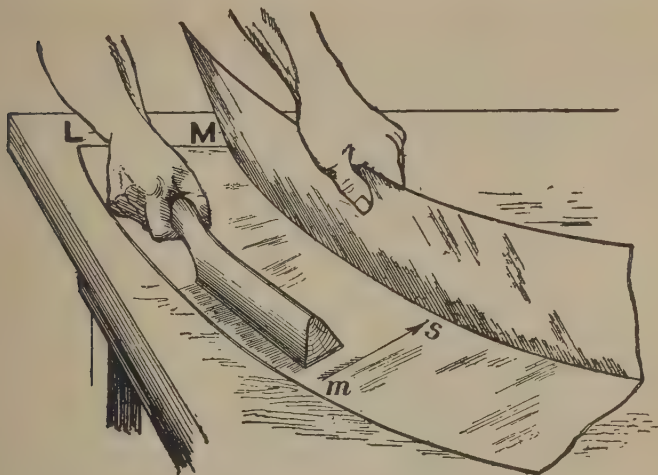
FIG. 6,543.—*Beating lead flashing, 8.* Beating back to shape after first bending.
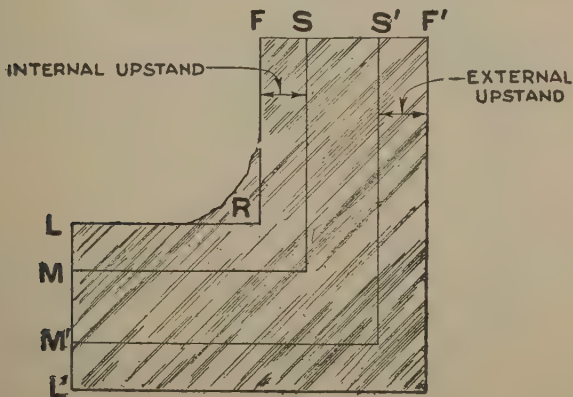
FIG. 6,544.—*Beating box gutter corner, 1.* Sheet marked and cut preliminary to beating.

Beating Corner for Box Gutter.—The making of a 90°
angle piece or corner consists in beating external and internal
angles on a piece of sheet lead.

The operations of beating the external angle will be first
described, then the internal angle.
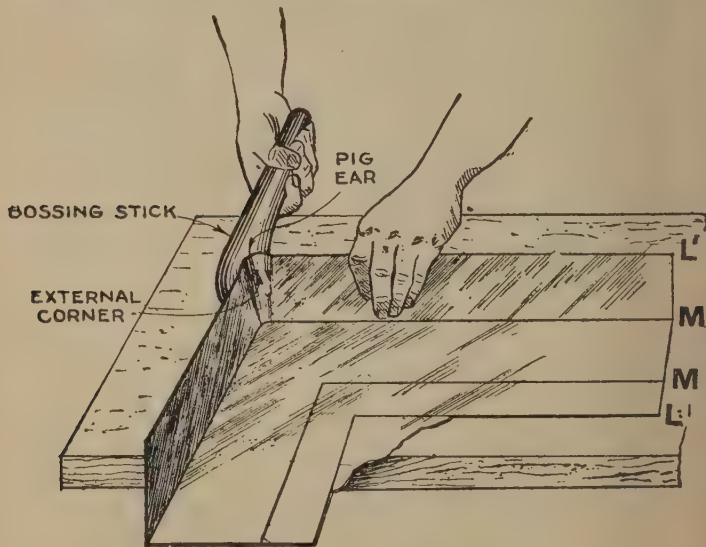
FIG. 6,545.—*Beating box gutter corner, 2.* Bossing up external corner.

A sheet of lead of proper size is first marked and cut as in
fig. 6,544.

The bending lines MS and M'S' are slightly indented with
the V dresser, similarly as in fig. 6535, to secure a sharp bend.

Bend up the external angle and boss up the lead at the ex-
ternal corner with a round mallet or bossing stick as in fig.
6,545.
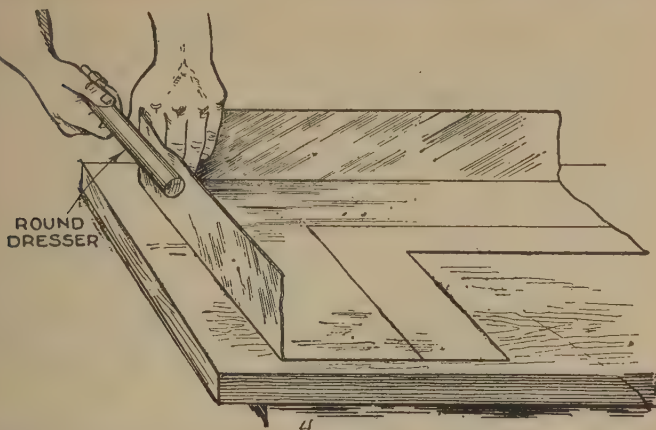
FIG. 6,546.—*Beating box gutter corner, 3.* Beating up external corner with round dresser; *first step.*
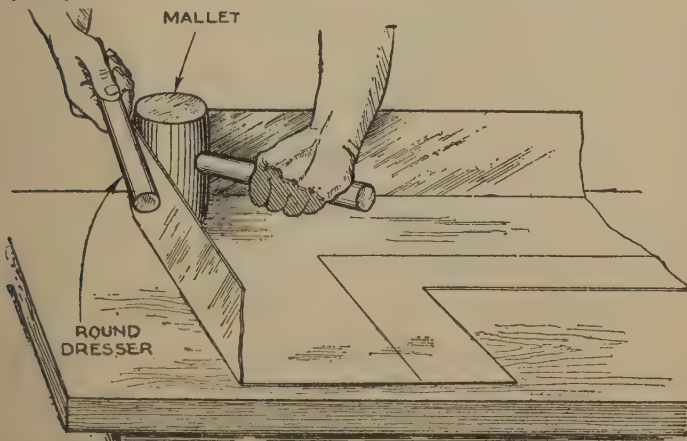
FIG. 6,547.—*Beating box gutter corner, 4.* Bring up external corner to 90° with bottom of gutter by beating against mallet; *second step.*

This operation causes the formation of a *pig ear* or projection of the lead at the corner due to compression. The pig ear should not be brought in too close as it is desirable to keep the corner circular in shape during the first part of the operation.

The lead is now worked up at the corner by using a round dresser as in fig. 6,546, after which it is brought up to 90°
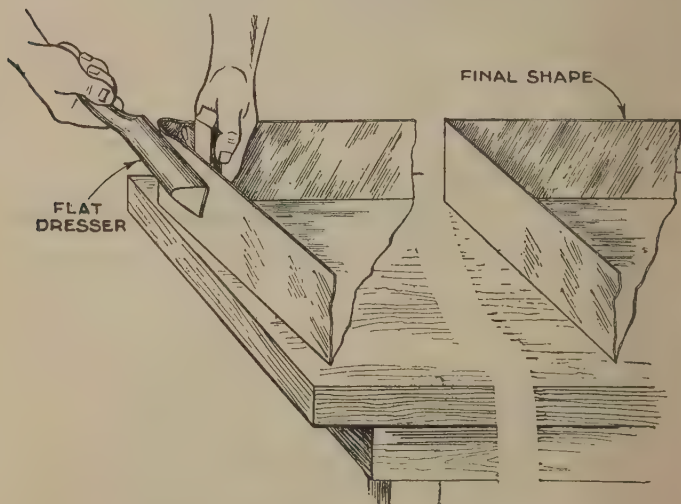
FIG. 6,548.—*Beating box gutter corner, 5.* Sharpening external angle of corner by beating with flat dresser against a flat dresser held inside the angle.

FIG. 6,549.—*Beating box gutter corner, 6.* Appearance of finished external angle of corner after cutting off pig's ear.

with the bottom of the gutter beating it against a mallet held on the inside as in fig. 6,547.

The final operation consists in sharpening the external angle by using two flat dressers as in fig. 6,548.

It remains now to beat the internal angle to finish the corner.
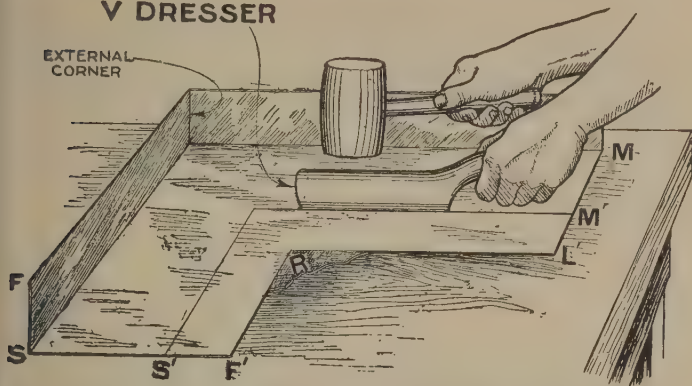
Fig. 6,550.—*Beating box gutter corner*, 7. Indenting internal bending line with V dresser.
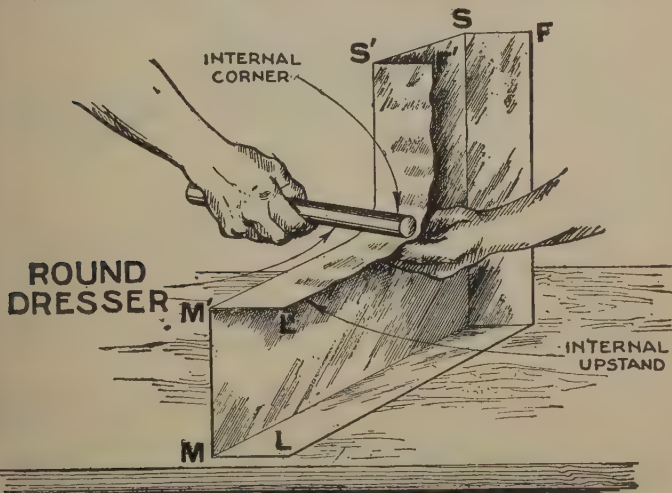
Fig. 6,551.—*Beating box gutter corner*, 8. First beating operation on internal corner with round dresser.

At this stage it should be noted that whereas the beating of the external corner introduces *compression* in the metal, the operations on the internal corner cause *tension*. On account of this, the metal is not cut to the internal bending line at the corner but a margin indicated by the area R, (fig. 6,544 and fig. 6,550) is left to provide metal for *drawing* the lead to make up for the thinning of the upstand due to tension.

The first operation consists of indenting the internal corner along the bending line as in fig. 6,550.
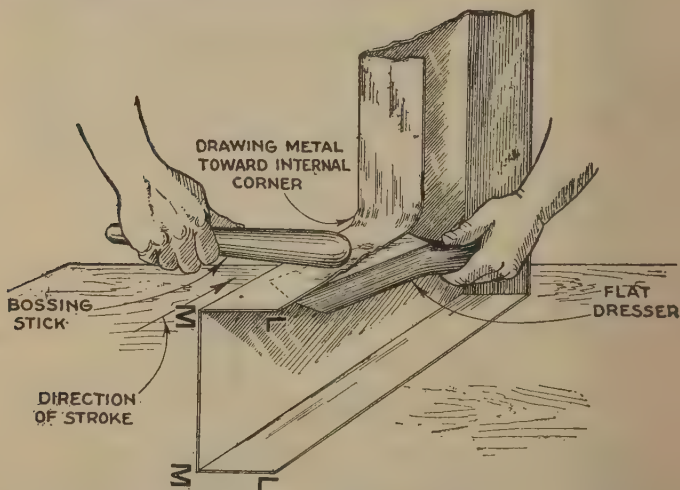
Fig. 6,552.—*Beating box gutter corner, 9.* Drawing metal toward internal corner by beating with round dresser or bossing stick using flat dresser as support.

Next the first operation in beating up the internal upstand is performed with a round dresser as in fig. 6,551, roughly beating it into the shape shown.

The effect of this operation is to thin out the metal of the upstand and on each side of the internal corner and to make up for this, the metal

must be drawn towards the internal corner by beating with a bossing stick and flat dresser as shown in fig. 6,552.

In beating, the strokes should be driven toward the corner as indicated by the arrow. The same operation is performed on the other side of the corner gradually piling up the metal toward the thin part at the corner without materially reducing the thickness of the run of the upstand.

By repeating the alternate operations of beating the corner
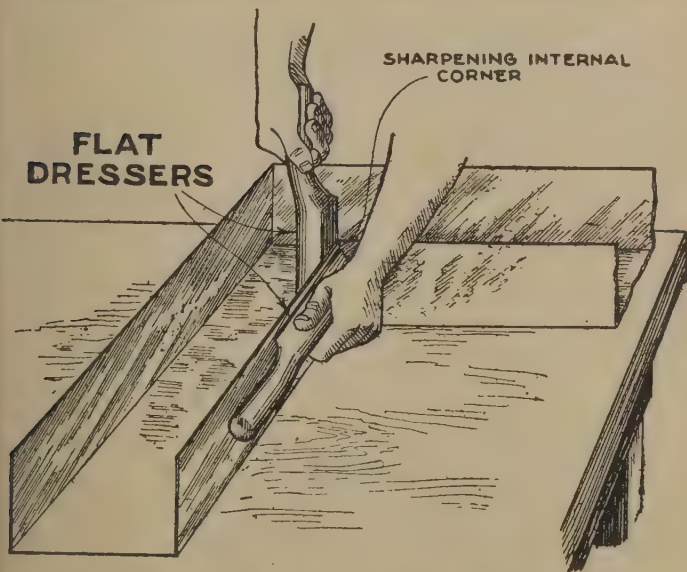
FIG. 6,553.—*Beating box gutter corner, 10.* Sharpening internal corner by beating with flat dresser using a second flat dresser for supporting the metal.

with the round dresser and drawing the metal from each side toward the corner the upstand is brought almost to the desired shape. The internal corner should not be sharpened until the upstand has been beaten a little over 90° with the bottom.

At this stage, sharpen the corner by holding a flat dresser against the outside and beating the inside with another flat dresser as shown in fig. 6,553.

Questions and Answers for Plumbers

Preliminary Test for License Applicants

What is meant by "Plumbing"?

Ans. It is the art of installing in buildings the pipes, fixtures, and other apparatus for bringing in the water supply and removing liquid and water-carried wastes.

What constitutes the plumbing system of a building?

Ans. It includes the water supply distributing pipes; the fixtures and fixture traps; the soil, waste and vent pipes; the house drain and house sewer; the storm-water drainage; with their devices, appurtenances, and connections, all within and adjacent to the building.

What is a water service pipe?

Ans. It is the pipe from the water main to the building served.

What is meant by water distribution pipes?

Ans. They are the pipes which convey water from the service pipes to the plumbing fixtures.

What constitutes the "plumbing fixtures"?

Ans. These are receptacles intended to receive and discharge water, liquid, or water-carried wastes into a drainage system with which they are connected.

Why must all plumbing fixtures be connected to a water source?

Ans. In order that they shall be provided with a sufficient amount of water to keep them in a serviceable and sanitary condition.

What is a trap?

Ans. This is a fitting or device so constructed as to prevent the passage of air or gas through a pipe without materially affecting the flow of sewage or waste water through it.

What is meant by the "vent pipes"?

Ans. Any pipe provided to ventilate a house-drainage system and to prevent trap syphonage and back pressure.

What is a local ventilating pipe?

Ans. A pipe through which foul air is removed from a room or a fixture.

What is a soil pipe?

Ans. Any pipe which conveys the discharge of water-closets, with or without the discharges from other fixtures, to the house drain.

What is a waste pipe?

Ans. A pipe which receives the discharge of any fixture, except water-closets, and conveys the same to the house drain, soil or waste stacks.

What constitutes a main?

Ans. The main of any system of horizontal, vertical or continuous piping is that part of such system which receives the wastes, vent or back vents, from fixture outlets or traps, direct or through branch pipes.

What is meant by Branch piping?

Ans. That part of the system which extends horizontally at a slight grade, with or without lateral or vertical extensions or vertical arms, from the main to receive fixture outlets not directly connected to the main.

What is a "stack"?

Ans. Stack is a general term for any vertical line of soil, waste or vent piping.

What is meant by the term "House drain"?

Ans. It is that part of the lowest horizontal piping of a house drainage system which receives the discharge from soil, waste and other drainage pipes inside the walls of any building

and conveys the same to the house sewer beginning 5 feet outside of the inner face of the building wall.

What is a house sewer?

Ans. It is that part of the horizontal piping of a house drainage system extending from the house drain 5 feet outside of the inner face of the building wall to its connection with the main sewer or cesspool and conveying the drainage of but one building site.

What is meant by the term "Pipe size" and "pipe length"?

Ans. The given caliber or size of pipes is for a normal internal diameter, except that other than iron pipe and brass pipe sizes are measured by their outside diameter. By the length of a pipe is meant the developed length, the length along the center line of pipe and fittings.

What is a dead end?

Ans. A branch leading from a soil, waste, vent, house drain, or house sewer, which is terminated at a developed distance of 2 feet or more by means of a cap, plug, or other fitting not used for admitting water to the pipe.

What are the rules as to workmanship and materials?

Ans. All work must be performed in a thorough, workmanlike manner and all material used in any drainage or plumbing system or part thereof shall be free from defects.

How is it possible to determine if the pipes used are of proper size and weight?

Ans. The length of each pipe, fitting trap fixture and device used in a plumbing or drainage system shall be stamped or

indelibly marked with the weight or quality thereof and the maker's mark or name.

What is the maximum length of "short branches" of 1½-inch lead pipe?

Ans.   5 feet.

What kind of material is employed for outside leaders and how should they be connected to the drainage system?

Ans.   Outside leaders shall be made of sheet metal or copper and shall be connected with the house drain system by means of a cast-iron pipe extending vertically 5 feet above the grade level.

When may the house sewer be of earthenware pipe?

Ans.   Only when a proper foundation can be obtained consisting of a natural bed of earth, rock, etc.

What kind of material must be employed in all main, soil, waste or vent pipes?

Ans.   All main, soil, waste and vent pipes must be made of iron, steel or brass.

What is meant by the term "riser lines" in a plumbing system?

Ans.   The term *riser* is generally applied to the vertical lines extending through the building from its connection with the house main.

May cast-iron pipe be used in a plumbing system?

Ans.   If the cast iron pipe conform to the standard specifications of the American Society for Testing Materials.   All

cast-iron pipe and fittings for underground use shall be coated with asphaltum or coal-tar pitch.

What are the requirements when brass and copper pipe is used?

Ans.   All brass and copper pipe shall conform to the standard specification of the A.S.T.M.

PIPE JOINTS AND FITTINGS

What are the rules when making connection between iron and brass pipes?

Ans.   Such connections must never be made with slip joints, and the threaded connection on the iron pipe must be of the same size as that on the brass pipe, and all burrs or cutting shall be removed.

What are the requirements when making joint in vitrified pipes?

Ans.   All joints in vitrified clay pipes, or between vitrified clay pipes and metals, shall be poured joints.

How should a calked joint be made?

Ans.   All calked joints shall be firmly packed with oakum or hemp and shall be secured only with pure lead, not less than one inch deep, well calked and no paint, varnish or putty will be permitted until the joint is tested.

How is an approved joint in lead pipes or between lead and brass or copper pipes made?

Ans.   Joints in lead pipes or between lead pipe, and brass or copper pipes, ferrules, soldering nipples, bushings or traps, in all cases on the sewer side of the trap and in concealed joints on the inlet side of the trap, shall be full-wiped joints with an exposed surface of the solder to each side of the joint of not less than three-quarters of an inch and a minimum thickness at the thickest part of the joint of not less than three-eighths of an inch.

What are the requirements when joints are made between lead and cast or wrought iron?

Ans.   The joints shall be made by means of a calking ferrule, soldering nipple or bushing.

When may slip joints and unions be used?

Ans.   Slip joints will be permitted only in trap seals or on the inlet side of the trap.   Unions on the sewer side of the trap shall be ground faced, and shall not be concealed or inclosed.

What is the term used for a fitting that makes an angle between two adjacent pipes?

Ans.   Elbow.

What is the name used for a fitting that has one side outlet at right angles to the run?

Ans.   Tee.

What is the name employed for a fitting having a larger size at one end than on the other?

Ans. Reducer.

What is the name of a fitting which has one side outlet at any angle other than 90°?

Ans. Wye.

What is the term generally employed for a piece of pipe which is threaded on both ends and less than 12 inches long?

Ans. Nipple.

What is the minimum diameter of brass pipes, when used in riser lines of a plumbing system?

Ans. One-half inch

What should be the minimum distance between the hot and cold water risers in a plumbing system?

Ans. The distance between the hot and cold water risers where a hot water supply is installed should not be less than 6 inches, and where conditions encountered are such that they cannot be readily placed 6 inches or more apart, the hot water riser should be covered with an approved insulating material, so as not to interfere with the prompt delivery of hot water to the faucet when required.

SOIL, WASTE AND VENT PIPES

What is the minimum size of a main vent pipe?

Ans. The size of a main vent pipe must never be less than 2 inches in diameter.

How are the required sizes of vent pipes determined?

Ans. The size of main vents or vent stacks shall be determined from the size of the soil or waste stack vented, and the total number of units drained into it. However, they must not be less than the following: for water-closets on three or more floors, 3 inches in diameter; for other fixtures where the building is less than 7 floors in height, 2 inches in diameter; where the building is less than 9 stories in height, 3 inches in diameter; from 8 to 16 stories and less in height, 4 inches in diameter, etc. For all fixtures other than water-closets and slop sinks for buildings more than 8 stories in height, the vent pipes may be one inch smaller in diameter than above stated.

What are the requirements in regards to size of long branch vent pipes?

Ans. No branch vent pipe shall be less than $1\frac{1}{2}$ inches in diameter, and for long branch vent pipes over 10 but not exceeding 25 feet in length, 2 inches in diameter; when over 25 but not more than 50 feet in length, 3 inches in diameter.

What is the longest branch vent pipes permitted?

Ans. No branch vent pipe must exceed 50 feet in length.

Where shall a clean out be placed in a vertical waste or soil stack?

Ans. A clean out easily accessible shall be provided and placed at the foot at each vertical waste or soil stack.

How may waste or soil pipes be protected against obstruction?

Ans. By the use of strong metallic strainers, placed over the outlets.

Should each building have soil and waste stacks?

Ans. Yes, every building in which plumbing fixtures are installed shall have a soil and waste stack extending full size through the roof.

How far above the roof must soil or vent pipe lines be carried?

Ans. All roof extensions of soil and vent stacks shall be run full size at least one foot above the roof coping and when the roof is used for other purposes than weather protection such extension shall not be less than 5 feet above the roof.

What special rules apply to soil and vent pipes used in a cold climate?

Ans. Where there is danger of frost closure, no roof extension shall be less than 4 inches in diameter. The change in diameter must be accomplished by the use of a long increase at least one foot below the roof, and where the access to the roof is difficult, a test opening shall be provided at this point.

May a vent or soil pipe be terminated within a distance of 2 feet from any door, window, scuttle or air shaft?

Ans. No, the roof terminal of any stack or vent, if within 12 feet of any door, window, scuttle or air shaft, shall extend at least 3 feet above the same.

May soil or vent lines be carried outside of buildings?

Ans. No soil or vent lines shall be installed or permitted outside of a building unless adequate provision is made to protect it from frost.

Where shall main vents be connected?

Ans. All main vents or vent stacks shall connect full size at their base to the main soil or vent pipe at or below the lowest fixture branch and shall extend undiminished in size above the roof, and shall be reconnected with the main soil or waste vent at least 3 feet above the highest fixture branch.

When offsets are made in vent lines how shall they be connected?

Ans. All vent and branch vent lines shall be connected and installed in such a way that they are free from drops or sags and be so graded and connected as to drip back to the soil or waste pipe by gravity. Where the vent pipes connect to a horizontal soil or waste pipe, the vent branch shall be taken off above the center line of the pipe and the vent pipes must rise vertically, or at an angle of 45° to the vertical to a point 6 inches above the fixture it is venting before offsetting horizontally or connecting to the branch, main waste or soil vent.

When may circuit or loop vents be employed?

Ans.   A circuit or loop vent will be permitted as follows: A branch soil or waste pipe to which two and not more than eight water-closets, pedestal urinals, trap standard slop sinks, or shower stall are connected in series, may be vented by a circuit or loop vent, which shall be taken off in front of the last fixture connection.   Where fixtures discharge above such branch, each branch shall be provided with a relief one-half the diameter of the soil or waste stack, taken off in front of the first fixture connection.

TRAPS

What is the required running diameter of traps for urinals?

Ans.   2 inches diameter.

What are the requirements for a permissible trap?

Ans.   Every trap shall be self-cleaning.   All traps used for bath tubs, lavatories, sinks and other similar fixtures shall be of lead, brass, cast iron, or of malleable iron galvanized or porcelain enameled inside.   Galvanized or porcelain enameled traps shall be extra heavy and shall have a full-bore smooth-interior waterway, with treads topped out of solid metal.

Where shall the fixture trap be placed relative to its fixture?

Ans.   The trap shall be placed as close to the fixture as possible, but shall in no case be placed more than 24 inches away from the fixture.

What are the requirements in regard to clean outs in fixture traps?

Ans. All traps, except water closet traps, shall be provided with an accessible brass trap screw of ample size, protected by the water seal.

May fixture traps be connected in series?

Ans. No, the discharge from any fixture shall never pass through more than one trap on its way to the house drain.

Must all fixture traps be protected against back pressure and syphonage?

Ans. Yes, every fixture trap shall be protected against syphonage and back pressure, and air circulation assured by means of a soil or waste stack vent, a continuous waste or soil vent, or a loop or circuit vent. No crown vent shall be installed.

Must trap levels be protected against frost and evaporation?

Ans. All traps shall be installed true with respect to their water seals and protected from frost and evaporation.

What is the seal of a trap?

Ans. It is the depth of the water between the dip and the outlet of the trap. The effectiveness of a trap depends always upon its water seal.

What is the dip of a trap?

Ans. The dip is that part of a trap that dips into the seal, and under which all waste matter must pass.

What are the terms used for some of the common styles of traps?

Ans.   S trap; $\frac{3}{4}$ S trap; $\frac{1}{2}$ S trap; grease traps; sand traps, etc.

What is meant by the term syphonage?

Ans.   By referring to an S trap it will be readily seen that the outlet forms a most perfect syphon, the part of the trap between the dip and the outlet forming the short side and the waste pipe from the outlet downward forming the long side.   When a large quantity of water is discharged from the fixture into the trap, the water fills the entire trap and waste pipe for some distance below the trap.   It is readily observed that the weight of the water is much greater at the outlet side than at the inlet side of the trap, and it tends to cause the water in trap to rise to the outlet and follow the larger body of water in the waste pipe, leaving the trap without any water to form its water seal.

What determines the resistance against syphonage in a trap?

Ans.   It is the depth of the water seal that determines the amount of resistance a trap will offer to being unsealed by syphonage.

THAWING ICE IN PIPES

How should service pipes be protected when exposed to frost?

Ans.   They should be protected by a sufficient amount of felt adequately supported by metal sleeving.

What precautions should be taken when thawing a frozen water pipe?

Ans.   If the thawing is accomplished by means of a blow torch or hot water, the thawing medium should be applied to the water supply end of the pipe, opening a faucet if possible to indicate when the flow of water starts.   It is well to keep in mind that the middle of the pipe should never be thawed first, because expansion of the water confined by ice on both sides may burst the pipe.

How should a waste or sewer pipe be thawed out?

Ans.   When thawing a waste or sewer pipe, always work upward from the lower end, to permit the water to drain away.

Enumerate and briefly discuss the most effective methods used to thaw out frozen water pipes.

Ans.   The method to be used will be determined by the amount of pipe to be thawed as well as the size and location of same.   For short lengths of exposed pipe, boiling hot water or hot cloths have proven to be effective.   If there is no danger of fire, or if the necessary precautions against fire are observed, a blow torch or burning newspaper run back and forth along the frozen water pipe gives quick results.   When the pipe to be thawed is located underground or otherwise inaccessible, the pipe should be disconnected at the house end, and boiling water directed through the opening by means of a small piece of auxiliary pipe or rubber tubing to which a funnel conveniently is attached.   Chemicals are more often resorted to as a preventive against frost, than for thawing pipes already frozen, and should if possible on account of their often dangerous characteristics, be avoided as a thawing medium.   When

a long section of inaccessible piping or leaders is to be thawed, low voltage electricity has been found to be effective. However, this latter method should never be utilized by the amateur, but should be performed only by fully qualified electrical engineers; due to the great multiplicity of precautions which must be observed in order to carry the thawing operations to a successful conclusion.

WATER-CLOSETS

What is the amount of water required for a water closet or pedestal urinal for one flushing?

Ans.   All water-closets or pedestal urinals shall be flushed by means of an approved tank or flush valve, having a flushing capacity of at least 4 gallons for water closets, and at least 2 gallons for urinals, and shall be properly adjusted so as to prevent the waste of water.

What is the minimum diameter required for the flush pipe in a water-closet flush tank?

Ans.   The flush pipe for water-closet flush tank shall not be less than $1\frac{1}{4}$ inches in diameter.

How many water-closets are required on a floor of a lodging house in which 24 persons reside?

Ans.   Two.   According to the plumbing code, there must be a sufficient number of water-closets on each floor, and so that in any case there never will be more than 15 persons to each water closet.

WATER SUPPLY

How shall the water supply to a building be controlled?

Ans. A main shut-off on the water supply line shall be provided near the curb. Accessible shut-offs shall also be provided on the main supply line just inside the foundation wall for each flat or apartment of a building, for each lawn sprinkler, for supply to each hot water tank, and for each water-closet.

Must water supply pipes and storage tanks be protected against frost?

Ans. Yes, all concealed water pipes and storage tanks and all exposed pipes or storage tanks subject to freezing temperatures shall be efficiently protected against freezing.

What material should water supply pipes and fittings consist of?

Ans. All water-supply pipes for a plumbing system shall be of lead, galvanized, wrought iron or steel, brass, copper or cast iron, with brass or galvanized cast iron or galvanized malleable iron fittings, and no pipe or fittings that have been used for other purpose shall be used for distribution of water.

What size of pipes are required in a water supply system?

Ans. All water supply pipes of any building shall be of a size sufficient to permit a continuous ample flow of water on all floors at any given time.

May the over-flow pipe from a house water supply tank be connected to the house drain?

Ans. No, all pipes from water supply tanks shall not be directly connected with any house drain, soil, or waste pipe,

but shall discharge upon the roof or be trapped into an open fixture.

REFRIGERATOR WASTE PIPES

May the refrigerator waste pipe be connected to the house drain?

Ans.   No, the waste pipe from a refrigerator or ice box, or any other receptacle where food is stored, shall not be connected with any house drain, soil or waste pipe.

How then shall refrigerator waste pipes be connected?

Ans.   Refrigerator, ice box or food container waste pipes shall in all cases, empty into an open sink that is properly supplied with water, and is connected trapped and vented, the same as any other fixtures, or they may discharge into a down spout, or rain leader trap located inside the building or into a cellar floor drain, but their ends must be left open.

What precautions should be observed when installing waste pipe lines for a refrigeration system?

Ans.   Refrigerator waste pipes shall not be less than $1\frac{1}{4}$ inches for one opening, $1\frac{1}{2}$ inches for three openings and for four to twelve openings shall not be less than 2 inches, and shall have at each opening a trap, and clean-out at angles so arranged as to properly clean and flush the pipe. Such waste pipes shall be continued at not less than full size through the roof, except where such fixtures are located in the basement or first floor.

CESSPOOLS AND SYPHON CHAMBERS

Where may cesspools be constructed?

Ans. Cesspools may be constructed only in non-residential areas where no sewer exists.

Where should cesspools be located relative to the building?

Ans. The distance between the cesspool and any building on the same lot as the building for which the use is intended, should not be less than 15 feet.

How should a cesspool be constructed?

Ans. A cesspool of average proportion should be 6 to 9 feet in diameter, lined with brick laid without mortar, and from 7 to 12 feet in depth. The brick lining should be 8 inches thick, and the bottom of stone concrete 6 inches thick. Sometimes
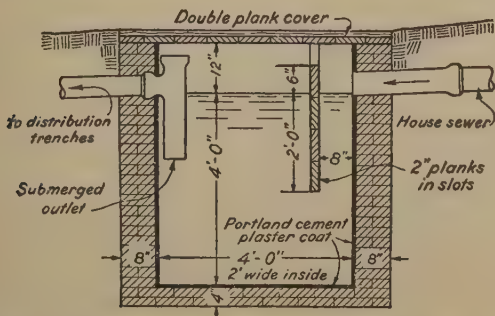
Fig. 1.—One-chamber septic tank—does nothing more than a tight cesspool. Brick construction, heavily plastered inside; size suitable for 180 to 280 gallons of sewage daily (nominally 4 to 7 persons).

the top is arched and capped on the ground surface by a cover of wood, stone or cast iron. When the walls are carried straight up, the top should be covered with impregnated boards or planks of substantial dimensions, and the entire structure may be conveniently hidden with a hedge or shrubbery.

How often should cesspools be cleaned and emptied?

Ans. Cesspools should be cleaned and emptied at least once a year, and the contents given a safe burial, with the requisite permission, vested in some municipal sewerage system authorities. After cleaning, the walls and bottom should be treated with a disinfectant or a deodorant.

When should cesspools be made of watertight construction?

Ans. Only in instances where facilities for removing and disposal of the contents in a clean and effective manner are available.

What is the difference between a septic tank and a cesspool?

Ans. A septic tank is simply a cesspool, regulated and controlled.

How can obstructions in a house sewer be removed?

Ans. By the use of some of the sample tools shown in fig. 2. Some of these tools can readily be made at home or by a blacksmith, and most of them should be obtainable for temporary use from a well-organized town or city sewer department. The purpose of the several tools shown is indicated in the notation.
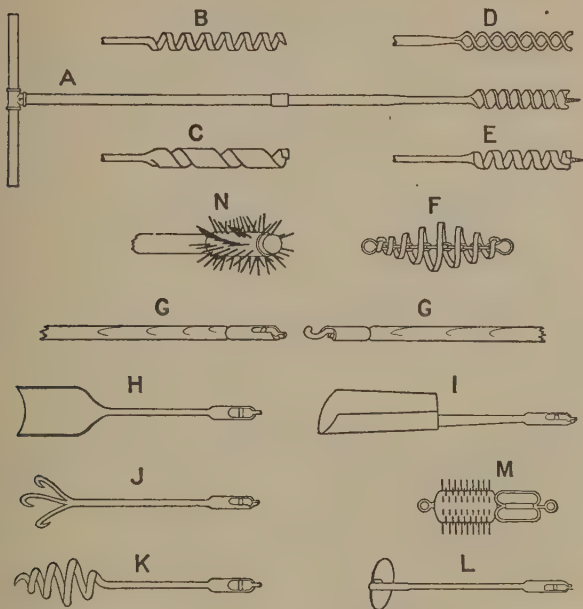
Fig. 2.—Sewer-cleaning tools and how to use them. **A**, ordinary $1\frac{1}{2}$ or 2 inch auger welded to a piece $1\frac{3}{4}$ inch extra strong wrought pipe about 5 feet long; the stem is lengthened by adding other pieces of pipe with screw couplings, and is fitted with a pipe handle; all cleaning work should proceed upstream; **B**, twist or open earth auger; **C**, ribbon or closed earth auger; **D**, spiral or coal auger; **E**, ship auger; **F**, root cutter; **G**, sewer rods, with hook coupling, usually of hickory or ash 1 or $1\frac{1}{4}$ inches in diameter and 3 or 4 feet long; **H**, gouge for cutting obstructions; **I**, scoop for removing sand or similar material; **J**, claw, and **K**, screw, for removing paper and rags; **L**, scraper; **M**, wire brush for removing grease, drawn back and forth with a wire or rope; **N**, home-made wire brush (for a 5 inch sewer use a $1\frac{1}{2}$ inch wooden pole to which is securely tacked a piece of heavy rubber, canvas or leather belting or harness leather $5\frac{1}{2}$ by 8 inches, spirally studded, as shown, with ordinary wire nails $1\frac{1}{2}$ inches in length).

What are the causes of sewer obstruction, and how should sewers be constructed to mitigate this trouble?

Ans. Causes of sewer obstruction may be any one of the following: Broken pipes, insufficient grade to give cleansing velocities, newspapers, rags, garbage or other solids in the sewage, congealing of grease in pipes and house sewer traps, and poor joint construction whereby rootlets grow into the sewer and choke it. A good grade and a good construction with particular care given to the joints, will avert or lessen these troubles. The sewer should be made perfectly straight with the interior of the joints scraped or swabbed smooth. When the joint-filling material has set, the hollows beneath the hubs should be filled with good earth free of stones, well stamped or puddled in place. It is important that like material be used at the sides of the pipe and above it for at least one foot. The back filling may be completed with scraper or plow. No running traps should be placed in the house sewer because it is liable to become obstructed and it prevents free movement of air through the sewer and soil stack. Conductors or drains for rain or other clean water should never be connected with the house sewer, but should discharge into a water-course or other outlet.

What is a syphon chamber and how does it work?

Ans. The purpose of the syphon is to secure intermittent discharge, thus allowing a considerable period of time for one dose to work off in the soil and for air to enter the soil spaces before another flush is received, and also to secure distribution over a larger area and in more even manner than where the sewage is allowed to dribble and produce the conditions of the old-fashioned sink drain, namely, a small area of water logged ground.
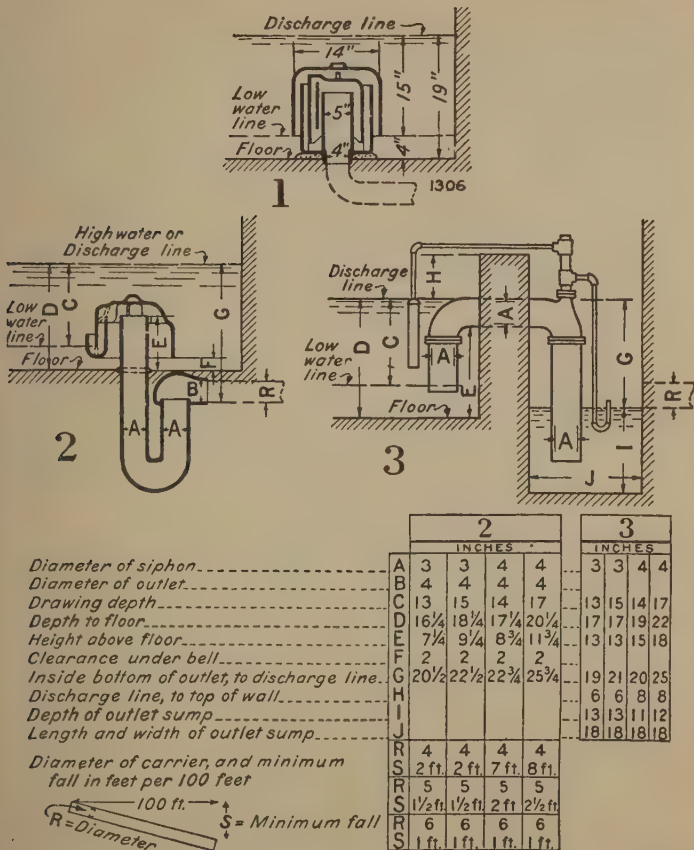
FIG. 3.—Three types of sewage syphon. The table gives dimensions for setting standard 3 and 4 inch syphons; also the appropriate size and grade of the sewer to carry the syphon discharge.

		2					3		
		INCHES					INCHES		
Diameter of siphon	A	3	3	4	4		3	3	4	4
Diameter of outlet	B	4	4	4	4					
Drawing depth	C	13	15	14	17		13	15	14	17
Depth to floor	D	16¼	18¼	17¼	20¼		17	17	19	22
Height above floor	E	7¼	9¼	8¾	11¾		13	13	15	18
Clearance under bell	F	2	2	2	2					
Inside bottom of outlet, to discharge line	G	20½	22½	22¾	25¾		19	21	20	25
Discharge line, to top of wall	H						6	6	8	8
Depth of outlet sump	I						13	13	11	12
Length and width of outlet sump	J						18	18	18	18
Diameter of carrier, and minimum fall in feet per 100 feet	R	4	4	4	4					
	S	2 ft.	2 ft.	7 ft.	8 ft.					
	R	5	5	5	5					
	S	1½ ft.	1½ ft.	2 ft.	2½ ft.					
	R	6	6	6	6					
	S	1 ft.	1 ft.	1 ft.	1 ft.					

R = Diameter   S = Minimum fall

Three types of sewage syphons are shown in fig. 3. In all, the essential principle is the same. A column of air is entrapped between two columns of water; when the water in the chamber rises to a predetermined height, called the discharge line, the pressure forces out the confined air, upsetting the balance and causing a rush of water through to the pipes on to the sewer. The entire operation is fully automatic and very simple. The syphons shown are commercial products and made of cast iron. Their simplicity and reliability are enhanced by the few and non-movable parts.

The table, fig. 3, lists stock sizes adapted to farm use. Manufacturers furnish full information for setting the syphons and putting them in operation.

For example take type 2, fig. 3. (1) set syphon trap (U-shaped pipe) plumb, making **E** (height from floor to top of long leg) as specified; (2) fill syphon trap with water till it begins to run out at **B**; (3) place bell in position of top of long leg, and the syphon is ready for service. Do not fill vent pipe on side of bell.
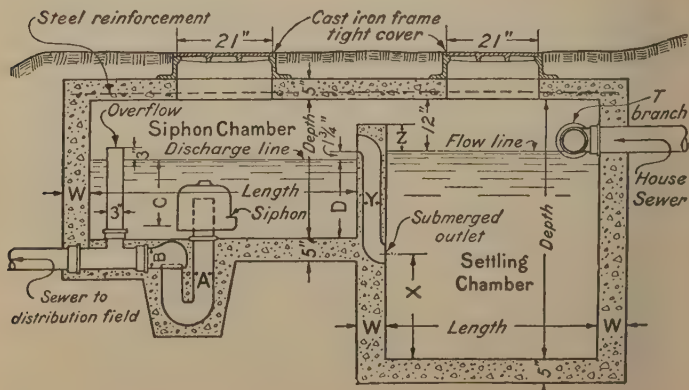
Fig. 4.—Typical two-chamber concrete septic tank.

The overhead syphon, type 3, fig. 3, may be installed readily in a tank already built by addition of an outlet pump. If properly set and handled, sewage syphons require very little attention and flush with certainty. However, like all plumbing fixtures, they are liable to stoppage, if rags, newspapers and similar solids get into the sewage. If fouling of the sniffling hole or vent prevents the entrance of sufficient air into the bell to lock the syphon properly, allowing sewage to dribble through, the remedy is to clean the syphon. It is well to remember that syphons are for handling liquid only, and sludge if allowed to accumulate will choke them.
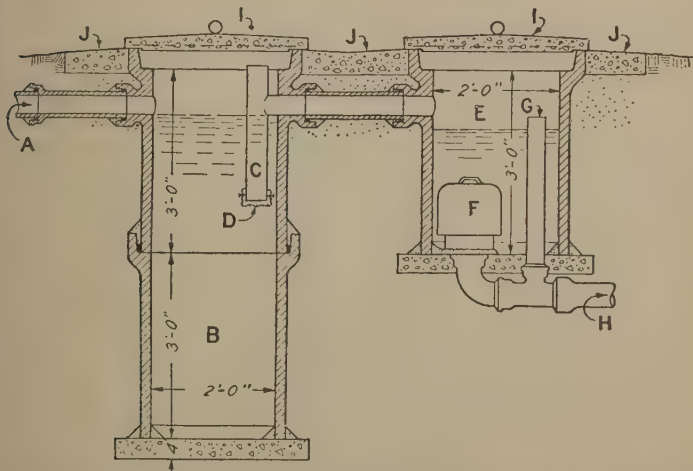
Fig. 5.—Two-chamber septic tank, simple and inexpensive, constructed of 24 inch vitrified sewer pipe, size suitable for 125 gallons of sewage daily (nominally 3 persons). **A**, house sewer; **B**, settling chamber, made of double T branch and one length of straight pipe, each 3 feet long and 2 feet in diameter, supported by 4 inches of concrete, all joints made water tight; **C**, submerged outlet, consisting of a metal T slipped into the sewer pipe branch; **D**, wire screen ¼ inch mesh; **E**, syphon chamber made of one T branch 3 feet long and 2 feet in diameter; **F**, syphon; **G**, 3 inch overflow; **H**, sewer to distribution field; **I**, tight cover with lifting ring; **J**, concrete protection around sewer pipe hubs.

TESTING

Is it necessary to have a plumbing system tested and inspected after completion, and by whom shall this test be made?

Ans. The entire plumbing and drainage system shall be tested by the plumber in the presence of a plumbing inspector or the proper administrative authority to insure the compliance with all the requirements of the Plumbing regulations and that the installation and construction of the system is in accordance with the approved plans and the permit.

How is this test accomplished?

Ans. By filling all the piping of the plumbing system by water or air. After the plumbing fixtures have been set and their traps filled with water, the entire drainage system shall be submitted to the final air-pressure test. The proper administrative authority may require the removal of any clean-outs to ascertain if the pressure has reached all parts of the system.

How shall the water test be made?

Ans. The water test may be applied to the drainage system in its entirety or in sections. If applied to the entire system, all openings in the piping shall be tightly closed, except the highest opening above the roof and the system filled with water to the point of overflow above the roof. If the system is tested in sections, each opening shall be tightly plugged, except the highest opening of the section under test, and each section shall be filled with water; but no section shall be tested with less than a 10 foot head of water or a 5 pound pressure of air. In testing successive sections at least the upper 10 feet of the next preceding section shall be re-tested, so that no joint

or pipe in the building shall have been submitted to a test of less than a 10 foot head of water or a 5 pound pressure of air.

How shall the air test be made?

Ans. By attaching the air compressor or test apparatus to any suitable opening, and closing all other air inlets and outlets to the system, then forcing air into the system until there is uniform pressure sufficient to balance a column of mercury 10 inches in height or 5 pounds per square inch on the entire system.

How long shall this air pressure be maintained?

Ans. For 15 minutes.

How shall the final air test be made?

Ans. In the final air test, the air machine shall be connected to any suitable opening or outlet, and air pressure equivalent to a one inch water column shall be applied and left standing at least 15 minutes. If there is no leakage or forcing of trap seals indicated by the fluctuation of the drum, float, or water column, the system shall be deemed air-tight.

In what order may the tests be made?

Ans. Separately or as follows: 1. The house sewer and all its branches from the property line to the house drain. 2. The house drain and yard drains, including all piping to the height of 10 feet above the highest point on the house drain, except the exposed connections to fixtures. 3. The soil, waste, vent, inside conductor, and drainage pipe which should be covered up before the building is inclosed or ready for completion. The test required for 2 and 3 may be combined. 4. The final test

of the whole system. 5. After each of the above tests has been made the proper administrative authority shall issue a written approval.

VALVES

What is a relief valve?

Ans. It is a valve arranged to provide an automatic relief in case of excess pressure.

What is a safety valve?

Ans. It is a relief valve for expansive fluids provided with a huddling and chamber to control the amount of blow back before the valve re-seats.

What is a stop valve?

Ans. It is a valve of the globe type used to shut off a line.

What is a back-pressure valve?

Ans. It is a valve similar to a low-pressure safety valve which is set to maintain a certain back pressure on feed operating pressure irrespective of pressure variations of the supply. The back-pressure valve is arranged to relieve any excess supply to atmosphere or elsewhere, and it opens and closes automatically as required to produce this result.

ELECTROLYSIS

What is meant by the term electrolysis?

Ans. It is generally applied to electrolytic corrosion due to electric current conduction by water, gas mains and metallic structures.

Where does electrolysis take place?

Ans. Along water mains or metallic structures, where the electric stray current leaves the metal for the ground, or some other conductor of less resistance.

Where is this electrolytic corrosion most common?

Ans. In densely populated areas, along electric railroad lines where track rails are utilized as a negative return circuit.

How can electrolysis be avoided or mitigated?

Ans. In lowering the voltage drop by increasing the metallic area of the negative return circuits, neighboring the water
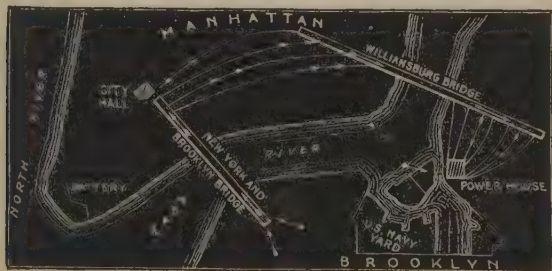
Electrolysis in lower New York. The figure illustrates current movements as discovered. The power house is located near the navy yard in Brooklyn. A portion of the returning currents, as shown by arrows, flows over the New York and Brooklyn bridge to Manhattan, thence north to Williamsburg bridge via underground mains, subway structures, and other metals, and passes over that bridge back to Brooklyn, thence through mains to rails and negatives, to power house. In this case damage may be expected at three points: 1, where currents leave bridge metals on the Manhattan side; 2, where they leave pipes to enter Williamsburg bridge; 3, where they leave same bridge for pipes in Brooklyn side. When the two bridge structures are connected in Manhattan as proposed, then there will be further changes in the direction of current. Before the Williamsburg bridge was built, these currents recrossed through the river bed, leaving mains all along the docks in the Manhattan side, for the river, and leaving the river for mains or other metals along the docks of the Brook.yn side. Traces of these currents have been found as far north as 23rd St., a distance of over two miles from the Brooklyn bridge. Since the Williamsburg bridge has been built, nearly all traces of these currents flowing north of it have disappeared, showing that the mass of metal composing the structure acts as a short circuit or path of lower resistance which carries practically all of the returning currents flowing from Manhattan back to Brooklyn.

mains.   In some cases insulating or high resistance pipe joints have been found to limit the conduction of stray electrical currents.

Name other methods of lessening the danger of electrolysis.

Ans.   By increasing the resistance of the road-bed, by making it dry and insulating the ties by creosote or similar preservative.

How may electric current be detected in a main?

Ans.   By means of a sensitive galvanometer which can be calibrated to show the potential drop along the pipe, measuring the distance, and calculating the cross-sectional area.   The cross-sectional area of the pipe being known, its resistance may be calculated from the known resistivity of steel (usually 11 times that of copper).   The potential drop divided by the resistance, gives the flow of current in the main.   By knowing the direction of the flow, its amount and the efficiency of corrosion, the actual damage being done by electrolysis may be calculated as a definite weight of metal per annum.

SPRINKLER LINES

What are the essential requirements of piping and apparatus for fire protection?

Ans.   It must be capable of producing without question, the desired performance, and it must be designed so as to function invariably regardless of age or weather requirements.

Who established rules for all kinds of fire protective apparatus?

Ans.   The National Board of Fire Underwriters and allied organizations.

How should the piping for an automatic sprinkler system be designed?

Ans. It must be designed so as to insure: 1. An adequate and reliable water supply. 2. Ample and complete distribution. 3. Proper protection against freezing.

What are the rules in regard to water supply?

Ans. It is generally considered necessary to have two sources of water supply, one which should require no manual operation. For example, a common arrangement is a gravity tank in combination with a fire department connection to be used when the apparatus arrives.

What are the N.B.F.U. rules in regards to location and spacing of sprinkler heads?

Ans. They take into account the type of building construction and the dimension of the bays. In general one sprinkler head is required for each 80 to 100 square feet of floor area.

What are the relations between the number of heads and branch pipes?

Ans. Piping should be so arranged that the number of heads on any branch pipe should not exceed eight.

What should be the size of riser lines in a sprinkler system?

Ans. Each riser in a sprinkler system should be of sufficient size to supply all the sprinklers connected to it on any one floor, or if there is no approved fire stop between the floors, the

riser should be of sufficient size to accommodate the total number of sprinklers.

Must riser and supply lines be protected against frost?

Ans.   They must be adequately protected against frost by means of insulating materials, if in exposed locations.

What type of valves may be used on a fire protective system?

Ans.   All valves must be of the O.S.& Y. pattern, and check valves should be installed in all sources of supply.   Each system should be provided with a gate valve so located as to control all sources of water supply except that from fire departmental sources.

What is a "dry system" and where is such system required?

Ans.   It is a system in which the piping is ordinarily filled with air at a pressure considerably lower than water pressure. When a sprinkler head opens, water enters the system and drives the air out ahead of it. This type of system is required in rooms which cannot be properly heated.

What is the most important feature of the dry pipe system?

Ans.   It is the dry pipe valve, a device which normally prevents water from entering the system but which opens when the air pressure is lowered, due to the opening of a head.

What is the water source for an automatic sprinkler system?

Ans.   Overhead gravity tanks are used as the initial supply for automatic sprinkler system and hose connections.

WATER TANKS

What materials are the tanks made of?

Ans. They may be made of either wood-staves or steel.

How are the required tank sizes determined?

Ans. The size of a tank for a given service is determined individually by the insurance authorities. In general when feeding sprinklers only the tank must have a capacity of 10,000 to 25,000 gallons and when feeding both sprinklers and hose a minimum capacity of 30,000 gallons.

What is the size of discharge pipes relative to tank capacity in an elevated gravity tank system?

Ans. Elevated gravity tanks must have a discharge pipe of not less than 6 inches size for tank sizes up to 25,000 gallons capacity, and generally not less than 8 inches for 30,000 up to 110,000 gallons and 10 inches for greater capacities.

How are the tanks protected against freezing?

Ans. The usual arrangement consists of a tubular steam heater to which a connection is made from the base of the tank discharge pipe. The heated water is carried up to the tank by a separate pipe. This arrangement permits the temperature of the coldest water to be observed readily and is by far the simplest and most reliable method. The coldest water should not be allowed to go below 40° F.

What are the regulations in regard to pressure tanks?

Ans. Pressure tanks for fire service are ordinarily kept two-thirds full of water, and with an air pressure on the surface of the

water of 75 pounds plus three times the pressure caused by the column of water in the sprinkler system above the tank bottom.

What are the capacities of pressure tanks?

Ans. The capacities are usually set by the insurance inspection authorities having a jurisdiction and is usually between 4,500 and 9,000 gallons per tank.

How should a pressure tank be designed?

Ans. It should be in accordance with the rules for the construction of unfired pressure vessels of the A.S.M.E.

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Plumbing Code

PLUMBING CODE

Recommended by the Subcommittee on Plumbing of the Department of Commerce Building Code Committee

ARTICLE I.—DEFINITIONS OF TERMS

SECTION 1. PLUMBING.—Plumbing is the art of installing in buildings the pipes, fixtures, and other apparatus for bringing in the water supply and removing liquid and water-carried wastes.

SEC. 2. PLUMBING SYSTEM.—The plumbing system of a building includes the water supply distributing pipes; the fixtures and fixture traps; the soil, waste, and vent pipes; the house drain and house sewer; the storm-water drainage; with their devices, appurtenances, and connections all within or adjacent to the building.

SEC. 3. WATER-SERVICE PIPE.—The water-service pipe is the pipe from the water main to the building served.

SEC. 4. WATER-DISTRIBUTION PIPES.—The water-distribution pipes are those which convey water from the service pipe to the plumbing fixtures.

SEC. 5. PLUMBING FIXTURES.—Plumbing fixtures are receptacles intended to receive and discharge water, liquid, or water-carried wastes into a drainage system with which they are connected.

SEC. 6. TRAP.—A trap is a fitting or device so constructed as to prevent the passage of air or gas through a pipe without materially affecting the flow of sewage or waste water through it.

SEC. 7. TRAP SEAL.—The trap seal is the vertical distance between the crown weir and the dip of the trap.

SEC. 8. VENT PIPE.—A vent pipe is any pipe provided to ventilate a house-drainage system and to prevent trap siphonage and back pressure.

SEC. 9. LOCAL VENTILATING PIPE.—A local ventilating pipe is a pipe through which foul air is removed from a room or fixture.

SEC. 10. SOIL PIPE.—A soil pipe is any pipe which conveys the discharge of water-closets, with or without the discharges from other fixtures, to the house drain.

SEC. 11. WASTE PIPE AND SPECIAL WASTE.—A waste pipe is any pipe which receives the discharge of any fixture, except water-

closets, and conveys the same to the house drain, soil, or waste stacks. When such pipe does not connect directly with a house drain or soil stack, it is termed a special waste.

Sec. 12. Main.—The main of any system of horizontal, vertical, or continuous piping is that part of such system which receives the wastes, vent or back vents, from fixture outlets or traps, direct or through branch pipes.

Sec. 13. Branch.—The branch of any system of piping is that part of the system which extends horizontally at a slight grade, with or without lateral or vertical extensions or vertical arms, from the main to receive fixture outlets not directly connected to the main.

Sec. 14. Stack.—Stack is a general term for any vertical line of soil, waste, or vent piping.

Sec. 15. House Drain.—The house drain is that part of the lowest horizontal piping of a house drainage system which receives the discharge from soil, waste, and other drainage pipes inside the walls of any building and conveys the same to the house sewer beginning 5 feet outside of the inner face of the building wall.

Sec. 16. House Sewer.—The house sewer is that part of the horizontal piping of a house drainage system extending from the house drain 5 feet outside of the inner face of the building wall to its connection with the main sewer or cesspool and conveying the drainage of but one building site.

Sec. 17. Size and Length.—The given caliber or size of pipe is for a nominal internal diameter, except that other than iron pipe size, brass pipe is measured by its outside diameter. The developed length of a pipe is its length along the center line of pipe and fittings.

Sec. 18. Dead End.—A dead end is a branch leading from a soil, waste, vent, house drain, or house sewer, which is terminated at a developed distance of 2 feet or more by means of a cap, plug, or other fitting not used for admitting water to the pipe.

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ARTICLE II.—GENERAL REGULATIONS

SEC. 19. GRADES OF HORIZONTAL PIPING.—All horizontal piping shall be run in practical alignment and at a uniform grade of not less than one-eighth of an inch per foot, and shall be supported or anchored at intervals not to exceed 10 feet. All stacks shall be supported at their bases, and all pipes shall be rigidly secured.

SEC. 20. CHANGE IN DIRECTION.—All changes in direction shall be made by the appropriate use of 45° wyes, half wyes, long sweep quarter bends, sixth, eighth, or sixteenth bends, except that single sanitary tees may be used on vertical stacks, and short quarter bends may be used in soil and waste lines where the change in direction of flow is from the horizontal to the vertical. Tees and crosses may be used in vent pipes.

SEC. 21. PROHIBITED FITTINGS.—No double hub, double T, or double sanitary T branch shall be used on soil or waste lines. The drilling and tapping of house drains, soil, waste, or vent pipes, and the use of saddle hubs and bands are prohibited.

SEC. 22. DEAD ENDS.—In the installation of any drainage system dead ends shall be avoided.

SEC. 23. PROTECTION OF MATERIAL.—All pipes passing under or through walls shall be protected from breakage.. All pipes passing through or under cinder concrete or other corrosive material shall be protected against external corrosion.

SEC. 24. WORKMANSHIP.—Workmanship shall be of such character as fully to secure the results sought to be obtained in all of the sections of this code.

SEC. 25. INSTALLATION OF PLUMBING BY OWNER.—All plumbing installed by the owner shall comply with the requirements of this code and in such event the word "owner" shall be substituted for the word "plumber" throughout this code.

ARTICLE III.—QUALITY AND WEIGHTS OF MATERIALS

SEC. 26. MATERIALS, QUALITY OF.—All materials used in any drainage or plumbing system, or part thereof, shall be free from defects.

SEC. 27. LABEL, CAST OR STAMPED.—Each length of pipe, fitting, trap, and device used in a plumbing or drainage system shall be stamped or indelibly marked with the weight or quality thereof and the maker's mark or name.

SEC. 28. VITRIFIED CLAY PIPE.—All vitrified clay pipe shall conform to the A. S. T. M. "Standard Specifications for Clay Sewer Pipe" (serial designation, C 13–24).

SEC. 29. CAST-IRON PIPE.—(*a*) *Quality.*—All cast-iron pipe and fittings shall conform to the A. S. T. M. "Standard Specifications for Cast-iron Soil Pipe and Fittings" (serial designation, A 74–18). (See note 24, p. 223:)

(*b*) *Coating.*—All cast-iron pipe and fittings for underground use shall be coated with asphaltum or coal-tar pitch.

SEC. 30. WROUGHT-IRON PIPE.—All wrought-iron pipe shall conform to the A. S. T. M. "Standard Specifications for Welded Wrought-Iron Pipe" (serial designation, A 72–07), and shall be galvanized.

SEC. 31. MILD-STEEL PIPE.—All steel pipe shall conform to the A. S. T. M. "Standard Specifications for Welded and Seamless Steel Pipe" (serial designation, A 53–27), and shall be galvanized.

SEC. 32. BRASS AND COPPER PIPE.—Brass and copper pipe shall conform, respectively, to the standard specifications of the A. S. T. M. for "Brass Pipe, Standard Sizes," and for "Copper Pipe, Standard Sizes" (serial numbers B 43–24 and B 42–24, respectively).

SEC. 33. LEAD PIPE, DIAMETER, WEIGHTS.—All lead pipe shall be of best quality of drawn pipe, of not less weight per linear foot than shown below.

(*a*) Lead soil, waste, vent, or flush pipes, including bends and traps (extra light):

| Internal diameter | Weights per foot | | Internal diameter | Weights per foot | |
Inches	Lbs.	Ozs.	Inches	Lbs.	Ozs.
1	2	--	2	4	--
1¼	2	8	3	4	12
1½	3	8	4	6	--

(b) Lead water-supply pipe above ground (strong):

Internal diameter Inches	Weights per foot Lbs.	Ozs.	Internal diameter Inches	Weights per foot Lbs.	Ozs.
½	2	--	1¼	4	12
⅝	2	8	1½	6	--
¾	3	--	1¾	6	8
1	4	--	2	7	--

(c) Lead water-supply pipe under ground (extra strong):

Internal diameter Inches	Weights per foot Lbs.	Ozs.	Internal diameter Inches	Weights per foot Lbs.	Ozs.
½	2	8	1¼	6	--
⅝	3	--	1½	7	8
¾	3	8	1¾	8	--
1	4	12	2	9	--

SEC. 34. SHEET LEAD.—Sheet lead shall weigh not less than 4 pounds per square foot.

SEC. 35. SHEET COPPER OR BRASS.—Sheet copper or brass shall be not lighter than No. 18 B. and S. gauge, except that for local and interior ventilating pipe it shall be not lighter than No. 26 B. and S. gauge.

SEC. 36. GALVANIZED SHEET IRON.—Galvanized sheet iron shall be not lighter than the following B. and S. gauge:

No. 26 for 2 to 12 inch pipe.
No. 24 for 13 to 20 inch pipe.
No. 22 for 21 to 26 inch pipe.

SEC. 37. THREADED FITTINGS.—(a) Plain screwed fittings shall be of cast iron, malleable iron, or brass of standard weight and dimensions. (b) Drainage fittings shall be of cast iron, malleable iron, or brass, with smooth interior waterway, with threads tapped out of solid metal. (c) All cast-iron fittings used for water-supply distribution shall be galvanized. (d) All malleable iron fittings shall be galvanized.

SEC. 38. CALKING FERRULES.—Brass calking ferrules shall be of the best quality red cast brass, with weights and dimensions in accordance with the following table:

Pipe size (inches)	Actual inside diameter	Length	Weight	
	Inches	Inches	Lbs.	Ozs.
2	2¼	4½	1	--
3	3¼	4½	1	12
4	4¼	4½	2	8

SEC. 39. SOLDERING NIPPLES AND BUSHINGS.—(a) Soldering nipples shall be of brass pipe, iron-pipe size, or of heavy, cast red brass not less than the following weights:

Diameters Inches	Weights Ozs.	Diameters Inches	Weights Lbs. Ozs.	
1¼	6	2½	1	8
1½	8	3	2	0
2	14	4	3	8

(b) Soldering bushings shall be of brass pipe, iron-pipe size, or of heavy, cast red brass.

SEC. 40. FLOOR FLANGES FOR WATER-CLOSETS.—Floor flanges for water-closets shall be not less than three-sixteenths of an inch thick, and of brass or cast iron.

ARTICLE IV.—JOINTS AND CONNECTIONS

SEC. 41. WATER AND AIR TIGHT JOINTS.—All joints and connections mentioned under this article shall be made permanently gas and water tight.

SEC. 42. VITRIFIED PIPE.—All joints in vitrified clay pipes, or between vitrified clay pipe and metals, shall be poured joints.

SEC. 43. CALKED JOINTS.—All calked joints shall be firmly packed with oakum or hemp, and shall be secured only with pure lead, not less than 1 inch deep, well calked, and no paint, varnish, or putty will be permitted until after the joint is tested.

SEC. 44. SCREW JOINTS.—All screw joints shall be American standard screw joints, and all burrs or cuttings shall be removed.

SEC. 45. CAST IRON.—Cast-iron joints may be either calked or screw joints made in the approved manner.

SEC. 46. WROUGHT IRON, STEEL, OR BRASS TO CAST IRON.—The joints may be either screwed or calked joints made in the approved manner.

SEC. 47. LEAD PIPE.—Joints in lead pipe or between lead pipe and brass or copper pipes, ferrules, soldering nipples, bushings, or traps, in all cases on the sewer side of the trap and in concealed joints on the inlet side of the trap, shall be full-wiped joints, with an exposed surface of the solder to each side of the joint of not less than three-quarters of an inch and a minimum thickness at the thickest part of the joint of not less than three-eighths of an inch.

SEC. 48. LEAD TO CAST IRON, STEEL, OR WROUGHT IRON.—The joints shall be made by means of a calking ferrule, soldering nipple, or bushing.

SEC. 49. SLIP JOINTS AND UNIONS.—Slip joints will be permitted only in trap seals or on the inlet side of the trap. Unions on the sewer side of the trap shall be ground faced, and shall not be concealed or inclosed.

SEC. 50. ROOF JOINTS.—The joint at the roof shall be made watertight by use of copper, lead, or iron plates or flashings.

SEC. 51. CLOSET, PEDESTAL URINAL AND TRAP STANDARD SLOP SINK, FLOOR CONNECTIONS.—A brass floor connection shall be wiped or soldered to lead pipe, an iron floor connection shall be calked to cast-iron pipe, or an iron floor connection calked or screwed to

wrought-iron pipe, and the floor connection bolted to an earthenware trap flange. A metal to earthenware, a metal to metal union, or a lead or asbestos gasket or washer shall be used to make a tight joint.

Sec. 52. Increasers and Reducers.—Where different sizes of pipes or pipes and fittings are to be connected, proper size increasers or reducers, pitched at an angle of 45° between the two sizes, shall be used.

Sec. 53. Prohibited Joints and Connections.—Any fitting or connection which has an enlargement, chamber, or recess with a ledge shoulder or reduction of the pipe area in the direction of the flow on the outlet or drain side of any trap is prohibited.

Sec. 54. Expansion Bolts.—Connections of wall hangers, pipe supports, or fixture settings with the masonry, stone, or concrete backing shall be made with expansion bolts without the use of wooden plugs.

Sec. 55. New Materials.—Any other material than that specified in this code, which the proper administrative authority approves as being equally efficient, may be permitted.

ARTICLE V.—TRAPS AND CLEAN OUTS

SEC. 56. TRAPS, KIND, AND MINIMUM SIZE.—Every trap shall be self-cleaning. Traps for bathtubs, lavatories, sinks, and other similar fixtures shall be of lead, brass, cast iron, or of malleable iron galvanized or porcelain enameled inside. Galvanized or porcelain-enameled traps shall be extra heavy and shall have a full-bore smooth-interior water-way, with threads tapped out of solid metal.

The minimum size (nominal inside diameter) of trap and waste branch for a given fixture shall not be less than that shown in the following table:

Kind of fixture	Size (in inches), trap and branch	Kind of fixture	Size (in inches), trap and branch
Bathtubs [1]	1½	Sinks, hotel or public	2
Bath, shower, stall [1]	2	Sinks, large hotel or public	2
Bath, sitz	1½	Sinks, small, pantry or bar	1¼
Bath, foot	1½	Sinks, dishwasher	1½
		Sinks, slop, with trap combined	3
Bidets	1½	Sinks, slop sink, ordinary [1]	2
Combination fixture	1½	Urinals, lip	1½
Drinking fountains	1¼	Urinals, troughs	2
Fountain cuspidors	1¼	Urinals, pedestal	3
		Urinals, stall	2
Floor drains	2	Washbasin [1]	1¼
Laundry trays	1½	Water-closet	3
Sinks, kitchen, residence	1½		

[1] The present tendency is toward an increase in the size of trap and waste pipe for this fixture, in order to reduce the time required for emptying it.

SEC. 57. TRAPS, PROHIBITED.—No form of trap which depends for its seal upon the action of movable parts or concealed interior partitions shall be used for fixtures.

SEC. 58. TRAPS, WHERE REQUIRED.—Each fixture shall be separately trapped by a water-seal trap placed as near to the fixture as possible, except that a set of not more than 3 laundry trays or lavatories or a set of 2 laundry trays and 1 sink may connect with a single trap, provided the trap is placed centrally and the branches connect into the trap seal at an angle of not more than 60° to the vertical arm. In no case shall the waste from a bathtub or other fixture discharge into a water-closet trap. No fixture shall be double trapped.

SEC. 59. WATER SEAL.—Each fixture trap shall have a water seal of not less than 2 inches, and not more than 4 inches.

SEC. 60. TRAP CLEAN OUTS.—Each trap, except those in combination with fixtures in which the trap seal is plainly visible and accessible, shall be provided with an accessible brass trap screw of ample size, protected by the water seal.

SEC. 61. TRAP LEVELS AND PROTECTION.—All traps shall be set true with respect to their water seals and protected from frost and evaporation.

SEC. 62. PIPE CLEAN OUTS.—The bodies of clean-out ferrules shall be made of standard pipe sizes, conform in thickness to that required for pipe and fittings of the same metal, and extend not less than one-quarter inch above the hub. The clean-out cap or plug shall be of heavy red brass not less than one-eighth inch thick and be provided with raised nut or recessed socket for removal.

SEC. 63. PIPE CLEAN OUTS—WHERE REQUIRED.—A clean out easily accessible shall be provided at the foot of each vertical waste or soil stack. There shall be at least two clean outs in the house drain—one at or near the base of the stack and the other, with full-size Y branch, inside the wall near the connection between the house drain and house sewer. Except for the latter, clean outs shall be of the same nominal size as the pipes up to 4 inches and not less than 4 inches for larger pipes. The distance between clean outs in horizontal soil lines shall not exceed 50 feet.

SEC. 64. MANHOLES.—All underground traps and clean outs of a building, except where clean outs are flush with the floor, and all exterior underground traps shall be made accessible by manholes with proper covers.

SEC. 65. CLEAN OUTS—EQUIVALENTS.—Any floor or wall connection of fixture traps when bolted or screwed to the floor or wall shall be regarded as a clean out.

SEC. 66. GREASE TRAPS.—When a grease trap is installed, it shall be placed as near as possible to the fixture from which it receives the discharge and should have twice the capacity of the discharge.

SEC. 67. SAND TRAPS.—Sand traps when installed should be so designed and placed as to be readily accessible for cleaning.

SEC. 68. BASEMENT FLOOR DRAINS.—Cellar or basement floor drains shall connect into a trap so constructed that it can be readily cleaned and of a size to serve efficiently the purpose for which it is intended. The drain inlet shall be so located that it is at all times in full view. When subject to back flow or back pressure, such drains shall be equipped with an adequate back-water valve.

SEC. 69. BACK-WATER VALVES.—Back-water valves shall have all bearing parts or balls of noncorrodible metal and so constructed as to insure a positive mechanical seal and remain closed except when discharging wastes.

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ARTICLE VI.—WATER SUPPLY AND DISTRIBUTION

SEC. 70. QUALITY OF WATER.—The quality of the water supply shall meet accepted standards of purity.

SEC. 71. DISTRIBUTION.—The water supply shall be distributed through a piping system entirely independent of any piping system conveying another water supply.

SEC. 72. WATER SERVICE.—The water-service pipe of any building shall be of sufficient size to permit a continuous ample flow of water on all floors at a given time.

SEC. 73. WATER SUPPLY TO FIXTURES.—All plumbing fixtures shall be provided with a sufficient supply of water for flushing to keep them in a sanitary condition. Every water-closet or pedestal urinal shall be flushed by means of an approved tank or flush valve of at least 4 gallons flushing capacity for water-closets and at least 2 gallons for urinals, and shall be adjusted to prevent the waste of water. The flush pipe for water-closet flush tanks shall be not less than 1¼ inches in diameter, and the water from flush tanks shall be used for no other purpose.

No water-closet or urinal bowl shall be supplied directly from a water-supply system through a flushometer or other valve unless such valve is set above the water-closet or urinal in a manner such as to prevent any possibility of polluting the water supply.

No plumbing fixture, device, or construction shall be installed which will provide a cross connection between a distributing system of water for drinking and domestic purposes and a drainage system, soil, or waste pipe so as to permit or make possible the back flow of sewage or waste into the water-supply system.

SEC. 74. SIZE OF WATER-SUPPLY PIPES.—The minimum size of water-service pipes from the curb to the dwelling shall be one-half inch, and to fixtures as follows:

	Inch		Inch
Sill cocks	½	Lavatories	⅜
Hot-water boilers	½	Bathtubs	½
Laundry trays	½	Water-closet tanks	⅜
Sinks	½		

SEC. 75. WATER-SUPPLY CONTROL.—A main shut-off on the water-supply line shall be provided near the curb. Accessible shut-offs shall be provided on the main supply line just inside the foundation wall for each flat or apartment of a building, for each lawn sprinkler, for supply to each hot water tank, and for each water-closet.

Sec. 76. Water-supply Pipes and Fittings—Material.—All water-supply pipes for a plumbing system shall be of lead, galvanized wrought iron or steel, brass, or cast iron, with brass or galvanized cast-iron or galvanized malleable-iron fittings. No pipe or fittings that have been used for other purposes shall be used for distributing water.

Sec. 77. Water Supply, Protection.—All concealed water pipes, storage tanks, flushing cisterns, and all exposed pipes or tanks subject to freezing temperatures shall be efficiently protected against freezing.

Sec. 78. Relief Valves.—Wherever a check valve is installed on the cold-water supply pipe between the street main and the hot-water tank there shall be installed on the hot-water distributing system a suitable relief valve.

Sec. 79. Pumps and Hydrants.—All pumps and hydrants shall be protected from surface water and contamination.

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ARTICLE VII.—PLUMBING FIXTURES

SEC. 80. MATERIALS.—All receptacles used as water-closets, urinals, or otherwise for the disposal of human excreta, shall be vitrified earthenware, hard natural stone, or cast iron white enameled on the inside.

SEC. 81. HOW INSTALLED.—All plumbing fixtures shall be installed free and open in a manner to afford access for cleaning. Where practical all pipes from fixtures shall be run to the wall, and no lead trap or pipe shall extend nearer to the floor than 12 inches unless protected by casing.

SEC. 82. WATER-CLOSET BOWLS.—Water-closet bowls and traps shall be made in one piece and of such form as to hold sufficient quantity of water, when filled to the trap overflow, to prevent fouling of surfaces, and shall be provided with integral flushing rims constructed so as to flush the entire interior of the bowl.

SEC. 83. FROST-PROOF CLOSETS—WHERE PERMITTED.—Frost-proof closets may be installed only in compartments which have no direct connection with a building used for human habitation or occupancy. The soil pipe between the hopper and the trap shall be 3 inches in diameter and shall be of lead, or cast iron enameled on the inside.

SEC. 84. FIXTURES PROHIBITED.—Fixed wooden wash trays or sinks shall not be installed in any building designed or used for human habitation. No new copper lined wooden bathtubs shall be installed, and an old fixture of this class taken out shall not be reconnected. Pan and valve plunger, offset washout and other water-closets having invisible seals or unventilated space, or walls not thoroughly washed at each flush shall not be used. Long hopper closets or similar appliances shall not hereafter be installed. No dry closet or chemical closet shall be installed in a dwelling.

SEC. 85. FLOOR DRAINS AND SHOWER DRAINS.—A floor drain or a shower drain shall be considered a fixture and provided with a strainer.

SEC. 86. FIXTURE STRAINERS.—All fixtures other than water-closets and pedestal urinals shall be provided with fixed strong metallic strainers with outlet areas not less than that of the interior of the trap and waste pipe.

SEC. 87. FIXTURE OVERFLOW.—The overflow pipe from a fixture shall be connected on the house or inlet side of the trap and be so arranged that it may be readily and effectively cleaned.

ARTICLE VIII.—VENTILATION OF ROOMS AND FIXTURES

SEC. 88. LOCATION OF FIXTURES.—No trapped plumbing fixtures shall be located in any room or apartment which does not contain a window placed in an external wall or is not otherwise provided with proper ventilation.

SEC. 89. VENTILATING PIPE, HOW CONNECTED.—Ventilation pipes from fixtures and toilet rooms shall be separate and distinct and have no connection whatever with the other ventilating ducts or pipes in the building.

ARTICLE IX.—SOIL, WASTE, AND VENT PIPES

SEC. 90. MATERIAL.—All main or branch soil, waste, and vent pipes within the building shall be of cast iron, galvanized steel or wrought iron, lead, brass, or copper, except that no galvanized steel or wrought iron pipe shall be used for underground soil or waste pipes.

SEC. 91. FIXTURE UNIT.—The following table, based on the rate of discharge from a lavatory as the unit, shall be employed to determine fixture equivalents:

	Fixture units
One lavatory or washbasin	1
One kitchen sink	1½
One bathtub	2
One laundry tray	3
One combination fixture	3
One urinal	3
One shower bath	3
One floor drain	3
One slop sink	4
One water-closet	6
One bathroom group consisting of 1 water-closet, 1 lavatory, and 1 bathtub and overhead shower; or of 1 water-closet, 1 lavatory, and 1 shower compartment	8

One hundred and eighty square feet of roof or drained area in horizontal projection shall count as one fixture unit.

SEC. 92. SOIL AND WASTE STACKS.—Every building in which plumbing fixtures are installed shall have a soil or waste stack, or stacks, extending full size through the roof. Soil and waste stacks shall be as direct as possible and free from sharp bends and turns. The required size of a soil or waste stack shall be determined from the distribution and total of all fixture units connected to the stack in accordance with the following table, except that no water-closets shall discharge into a stack less than 3 inches in diameter:

Maximum fixture units on one stack

Diameter (inches)	With "sanitary T" inlets		With all 45° Y or "combination Y and one-eighth bend" inlets		Maximum length, including extension as vent
	In one branch interval [1]	On any one stack	In one branch interval [1]	On any one stack	
					Feet
1¼	1	1	1	1	50
1½	2	8	4	12	65
2	9	16	15	36	85
3	24	48	45	72	212
4	144	256	240	384	300
5	324	680	540	1,020	390
6	672	1,380	1,122	2,070	510
8	2,088	3,600	3,480	5,400	750

[1] The term "branch interval" shall be interpreted to mean a vertical length of stack, not less than 8 feet, within which a branch or branches are connected, and the total fixture units on all branches connected to a stack within any 8-foot length shall not exceed the maximum permitted by the table in one "branch interval."

SEC. 93. SOIL AND WASTE STACKS, FIXTURE CONNECTIONS.—All soil and waste stacks and branches shall be provided with correctly faced inlets for fixture connections.

SEC. 94. CHANGING SOIL AND VENT PIPES.—In existing buildings where the soil or waste vent pipe is not extended undiminished through or above the roof, or where there is a sheet-metal soil or waste vent pipe, and the fixture is changed in style or location or is replaced, a soil or waste vent pipe of the size and material prescribed for new work shall be installed.

SEC. 95. PROHIBITED CONNECTIONS.—No fixture connection shall be made to a lead bend or branch of a water-closet or similar fixture. No soil or waste vent, circuit or loop vent above the highest installed fixture on the branch or main shall thereafter be used as a soil or waste pipe.

SEC. 96. SOIL AND WASTE PIPE PROTECTED.—No soil or waste stack shall be installed or permitted outside a building unless adequate provision is made to protect it from frost.

SEC. 97. ROOF EXTENSIONS.—All roof extensions of soil and waste stacks shall be run full size at least 1 foot above the roof, and when the roof is used for other purposes than weather protection such extension shall not be less than 5 feet above the roof.

When there is danger of frost closure, no roof extension shall be less than 4 inches in diameter. Change in diameter shall be made by use of a long increaser at least 1 foot below the roof, and where access to the roof is difficult a test opening shall be provided at this point.

SEC. 98. TERMINALS.—The roof terminal of any stack or vent, if within 12 feet of any door, window, scuttle, or air shaft, shall extend at least 3 feet above the same.

SEC. 99. TERMINALS ADJOINING HIGH BUILDINGS.—No soil, waste, or vent pipe extension of any new or existing building shall be run or placed on the outside of a wall, but shall be carried up in the inside of the roof.

In the event that a new building is built higher than an existing building, the owner of the new building shall not locate windows within 12 feet of any existing vent stack on the lower building unless the owner of such new building shall defray the expenses or shall himself make such alteration to conform with section 98 of this article.

It shall be the duty of the owner of the lower or existing building to make such alteration therein upon the receipt in advance of money or security therefor, sufficient for the purpose, from the owner of the new or higher building or to permit, at the election of the owner of the new or higher building, the making of such alteration by the owner of said new or higher building.

SEC. 100. TRAPS PROTECTED, VENTS.—Every fixture trap shall be protected against siphonage and back pressure, and air circulation

assured by means of a soil or waste stack vent, a continuous waste or soil vent, or a loop or circuit vent. No crown vent shall be installed.

SEC. 101. DISTANCE OF VENT FROM TRAP SEAL.—No trap shall be placed more than 5 feet, horizontal developed length, from its vent. The distance shall be measured along the central line of the waste or soil pipe from the vertical inlet of the trap to the vent opening. The vent opening from the soil or waste pipe, except for water-closets and similar fixtures, shall not be below the dip of the trap.

SEC. 102. MAIN VENTS TO CONNECT AT BASE.—All main vents or vent stacks shall connect full size at their base to the main soil or waste pipe at or below the lowest fixture branch and shall extend undiminished in size above the roof or shall be reconnected with the main soil or waste vent at least 3 feet above the highest fixture branch.

SEC. 103. VENTS, REQUIRED SIZES.—The required size of main vents or vent stacks shall be determined from the size of the soil or waste stack vented, the total number of fixture units drained into it, and the developed length of the vent, in accordance with the following table, interpolating when necessary between permissible lengths of vent given in the table:

Maximum permissible length of vents (in feet) for soil and waste stacks

Diameters of soil or waste stack (inches)	Number of fixture units	Diameter of vent (in inches)									
		1¼	1½	2	2½	3	4	5	6	8	10
1¼	1	45									
1½	Up to 8	35	60								
2	Up to 18	30	50	90							
2½	Up to 36	25	40	75	105						
3	12		31	120	180	212					
3	18		18	70	180	212					
3	24		12	50	130	212					
3	36		8	35	93	212					
3	48		7	32	80	212					
3	72		6	22	65	212					
4	24			25	110	200	300	340			
4	48			16	65	115	300	340			
4	96			12	45	84	300	340			
4	144			9	36	72	300	340			
4	192			8	30	64	282	340			
4	264			7	20	56	245	340			
4	384			5	18	47	206	340			
5	72					40	65	250	300	440	
5	144					30	47	180	300	440	
5	288					20	32	124	300	440	
5	432					16	24	94	320	440	
5	720					10	16	70	225	440	
5	1,020					8	13	58	180	440	
6	144					27	108	340	510		
6	288					15	70	220	510	630	
6	576					10	43	150	425	630	
6	864					7	33	125	330	630	
6	1,296					6	25	92	240	630	
6	2,070					4	21	75	186	630	
8	320						42	144	400	750	900
8	640						30	86	260	750	900
8	960						22	60	190	750	900
8	1,500						16	40	125	525	900
8	2,500						12	28	90	370	900
8	4,160						7	22	62	252	840
8	5,400						5	17	52	212	705

Sec. 104. Branch and Individual Vents.—No vents shall be less than 1¼ inches in diameter. For 1¼ and 1½ inch wastes the vent shall be of the same diameter as the waste pipe, and in no case shall a branch or main vent have a diameter less than one-half that of the soil or waste pipe served, and in no case shall the length of a branch vent of given diameter exceed the maximum length permitted for the main vent serving the same size soil or vent stack.

Sec. 105. Vent-Pipe Grades and Connections.—All vent and branch vent pipes shall be free from drops or sags and be so graded and connected as to drip back to the soil or waste pipe by gravity. Where vent pipes connect to a horizontal soil or waste pipe, the vent branch shall be taken off above the center line of the pipe, and the vent pipe must rise vertically or at an angle of 45° to the vertical to a point 6 inches above the fixture it is venting before offsetting horizontally or connecting to the branch, main waste, or soil vent.

Sec. 106. Circuit and Loop Vents.—A circuit or loop vent will be permitted as follows: A branch soil or waste pipe to which two and not more than eight water-closets, pedestal urinals, trap standard slop sinks, or shower stalls are connected in the series may be vented by a circuit or loop vent, which shall be taken off in front of the last fixture connection. Where fixtures discharge above such branch, each branch shall be provided with a relief one-half the diameter of the soil or waste stack, taken off in front of the first fixture connection.

Sec. 107. Vents not Required.—No vents will be required on a down spout or rain leader trap, a back-water trap, a subsoil catch basin trap, or on a cellar floor drain, provided the cellar floor drain branches into the house drain on the sewer side at a distance of 5 feet or more from the base of the stack.

Where bathrooms or water-closets or other fixtures are located on opposite sides of a wall or partition or directly adjacent to each other within the prescribed distance, such fixtures may have a common soil or waste pipe and common vent.

ARTICLE X.—HOUSE DRAINS AND SEWERS

SEC. 108. INDEPENDENT SYSTEM.—The drainage and plumbing system of each new building and of new work installed in an existing building shall be separate from and independent of that of any other building, except as provided below, and every building shall have an independent connection with a public or private sewer when available.

Exception.—Where one building stands in the rear of another building on an interior lot and no private sewer is available or can be constructed to the rear building through adjoining alley, court, yard, or driveway, the house drain from the front building may be extended to the rear building and the whole will be considered as one house drain.

SEC. 109. OLD HOUSE SEWERS AND DRAINS.—Old house sewers and drains may be used in connection with new buildings or new plumbing only when they are found, on examination and test, to conform in all respects to the requirements governing new sewers or drains, as prescribed in this code. If the old work is found defective, the proper administrative authority shall notify the owner to make the necessary changes to conform with this code.

SEC. 110. CONNECTIONS WITH CESSPOOLS.—When a sewer is not available, drain pipes from buildings shall be connected with approved private sewage disposal works.

SEC. 111. EXCAVATIONS.—Each system of piping shall be laid in a separate trench, provided that drainage trenches may be benched not less than 18 inches for lighter piping, if not in violation of any city regulation prescribed for their installation. Where a double system of drainage is installed, the sanitary and surface house sewers or drains may be laid side by side in one trench.

Tunneling for distances not greater than 6 feet is permissible in yards, courts, or driveways of any building site. When pipes are driven, the drive pipe shall be at least one size larger than pipe to be laid.

All excavations required to be made for the installation of a house-drainage system, or any part thereof within the walls of a building, shall be open trench work. All such trenches and tunnels shall be kept open until the piping has been inspected, tested, and approved.

SEC. 112. HOUSE DRAINS UNDERGROUND.—Whenever possible all house drains shall be brought into the building below the basement or cellar floor.

Sec. 113. Material.—(a) The house sewer beginning 5 feet outside of the inner face of the building wall shall be of cast iron or of vitrified clay pipe; (b) the house drain when underground shall be of lead, brass, or cast iron; (c) the house drain when above ground shall be of cast iron, galvanized wrought iron or steel, lead or brass, approved standards. (See Art. III, secs. 26 to 33, inclusive.)

Sec. 114. Depth of Drains and Sewers.—No house sewer or underground house drain shall be laid parallel to or within 3 feet of any bearing wall, which might be thereby weakened. The house sewer and drains shall be laid at sufficient depth to protect them from frost.

Sec. 115. Size of Drains, Sewers, and Horizontal Branches.— The required size of sanitary house drains, sanitary house sewers, and horizontal branches shall be determined on the basis of the total number of fixture units drained by them in accordance with the following table:

Sanitary system only

Diameter of pipe (inches)	Maximum number of fixture units			Diameter of pipe (inches)	Maximum number of fixture units		
	Slope, ⅛-inch fall to 1 foot	Slope, ¼-inch fall to 1 foot	Slope, ½-inch fall to 1 foot		Slope, ⅛-inch fall to 1 foot	Slope, ¼-inch fall to 1 foot	Slope, ½-inch fall to 1 foot
1¼	1	1	1	5	162	216	264
1½	2	2	3	6	300	450	600
2	5	¹6	¹8	8	990	1,392	2,220
3	²15	²18	²21	10	1,800	2,520	3,900
4	84	96	114	12	3,084	4,320	6,912

¹ No water-closet shall discharge into a drainpipe less than 3 inches in diameter.
² Not more than two water-closets shall discharge into any 3-inch horizontal branch, house drain, or house sewer.

The required sizes of storm-water house drains and house sewers and other lateral storm drains shall be determined on the basis of the total drained area in horizontal projection in accordance with the following table:

Storm systems only

Diameter of pipe (inches)	Maximum drained roof area (square feet)¹			Diameter of pipe (inches)	Maximum drained roof area (square feet)¹		
	Slope, ⅛-inch fall to 1 foot	Slope, ¼-inch fall to 1 foot	Slope, ½-inch fall to 1 foot		Slope, ⅛-inch fall to 1 foot	Slope, ¼-inch fall to 1 foot	Slope, ½-inch fall to 1 foot
3	865	1,230	1,825	8	11,115	15,745	24,890
4	1,860	2,610	4,170	10	19,530	27,575	43,625
5	3,325	4,715	7,465	12	31,200	44,115	69,720
6	5,315	7,515	11,875	14	42,600	60,000	95,000

¹ The calculations in this table are based on a rate of rainfall of 4 inches per hour.

Sec. 116. Combined Storm and Sanitary Sewer Systems.—
Whenever a combined sewer system is employed, the required size
of the house drain or house sewer shall be determined by multiplying
the total number of fixture units carried by the drain or sewer by
the conversion factor corresponding to the drained area and total
fixture units, adding the product to the drained area and applying
the sum to the preceding table for storm-water sewers section 115.
No combined house drain or house sewer shall be less than 4 inches
in diameter, and no combined house drain or house sewer shall be
smaller in size than that required for the same number of fixture units
or for the same roof·area in separate systems.

Conversion factors for combined storm and sanitary system

Drained roof area, in square feet	Number of fixture units on sanitary system															
	Up to 6	7 to 18	19 to 36	37 to 60	61 to 96	97 to 144	145 to 216	217 to 324	325 to 486	487 to 732	733 to 1,098	1,099 to 1,644	1,645 to 2,466	2,467 to 3,702	3,703 to 5,556	Over 5,556
Up to 120	180	105	60	45	30	22	18	15	12	10	9.2	8.4	8.2	8.0	7.9	7.8
121 to 240	180	98	57	43	29	21	17.6	14.7	11.8	9.9	9.1	8.3	8.1	8.0	7.9	7.8
241 to 480	120	75	50	39	27	20	16.9	14.3	11.5	9.7	8.8	8.2	8.0	7.9	7.8	7.7
481 to 720	75	62	42	35	24	18	15.4	13.2	10.8	9.2	8.6	8.1	7.9	7.9	7.9	7.7
721 to 1,080	54	42	33	29	20	15	13.6	12.1	10.1	8.7	8.3	8.0	7.6	7.8	7.7	7.6
1,081 to 1,620	30	18	16	15	12	11.5	11.1	10.4	9.8	8.4	8.1	7.9	7.7	7.7	7.6	7.5
1,621 to 2,430	15	12	11	10.5	9.1	8.8	8.6	8.3	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.4
2,431 to 3,645	7.5	7.2	7.0	6.9	6.6	6.5	6.4	6.3	6.2	6.3	6.4	6.4	6.8	7.0	7.1	7.2
3,646 to 5,460	2.0	2.4	3	3.3	4.1	4.2	4.3	4.4	4.6	4.7	5.0	5.1	6.1	6.6	6.9	6.9
5,461 to 8,190	0	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.8	3.2	3.7	4.6	5.0	5.6	6.2	6.4
8,191 to 12,285	0	0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.6	2.7	3.5	4.5	5.2	5.6
12,286 to 18,420	0	0	0	2.0	2.1	2.1	2.2	2.2	2.2	2.3	2.3	2.4	2.6	3.2	4.2	4.7
18,421 to 27,630	0	0	0	0	2.0	2.1	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.5	2.8	3.1
27,631 to 40,945	0	0	0	0	0	2.0	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.4	2.4
40,946 to 61,520	0	0	0	0	0	0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Over 61,520	0	0	0	0	0	0	0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0

Sec. 117 House Sewer in Made Ground.—The house sewer
when laid in made or filled-in ground shall be of vitrified clay pipe,
laid on bed of approved grillage or concrete, or of cast-iron pipe,
A. S. T. M. approved standards.

Sec. 118. Drainage Below Sewer Level.—In all buildings in
which the whole or part of the house drainage and plumbing system
thereof lies below the crown level of the main sewer, sewage or house
wastes shall be lifted by approved artificial means and discharged
into the house sewer.

Sec. 119. Sumps and Receiving Tanks.—All subhouse drains
shall discharge into an air-tight sump or receiving tank so located as
to receive the sewage by gravity, from which sump or receiving tank
the sewage shall be lifted and discharged into the house sewer by
pumps, ejectors, or any equally efficient method. Such sumps
shall be either automatically discharged or be of sufficient capacity
to receive the house sewage and wastes for not less than 24 hours.

Sec. 120. Ejectors, Vented.—The soil or vent pipe leading to
an ejector or other appliance for raising sewage or other waste

matter to the street sewer shall, where a water-closet or closets are installed, be provided with a vent pipe not less than 4 inches in diameter, and where fixtures other than water-closets are installed the waste vent pipe shall be the same diameter as the waste pipe.

SEC. 121. MOTORS, COMPRESSORS, ETC.—All motors, air compressors, and air tanks shall be located where they are open for inspection and repair at all times. The air tanks shall be so proportioned as to be of equal cubical capacity to the ejectors connected therewith, in which there shall be maintained an air pressure of not less than 2 pounds for each foot of height the sewage is to be raised.

SEC. 122. EJECTORS FOR SUBSOIL DRAINAGE.—When subsoil catch basins are installed below the sewer level, automatic water ejectors provided with a ball float attached to the main water supply shall be used. Such ejectors or any device raising subsoil water shall discharge into a properly trapped fixture or into a storm-water drain.

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ARTICLE XI.—STORM-WATER DRAINS

SEC. 123. DRAINAGE OF YARDS, AREAS, AND ROOFS.—All roofs and paved areas, yards, courts, and courtyards shall be drained into the storm-water sewerage system or the combined sewerage systems, but not into sewers intended for sewage only. When drains used for this purpose are connected with the combined sewerage systems, they shall be effectually trapped, except roof leaders and conductors, where the roof or gutter opening is located not less than 12 feet from a door, window scuttle, or air shaft. One trap may serve for all such connections, but traps must be set below the frost line or on the inside of the building. Where there is no sewer accessible, such connections shall be discharged into the public gutter, unless otherwise permitted by the proper authorities, and in such case need not be trapped.

SEC. 124. SIZE OF GUTTERS AND LEADERS.—No gutter or inside leader shall be of less size than the following:

Area of roof (in square feet)	Gutter	Leader
	Inches	*Inches*
Up to 90	3	1¼
91 to 270	4	2
271 to 810	4	3
811 to 1,800	5	3
1,801 to 3,600	6	4
3,601 to 5,500	8	5
5,501 to 9,600	10	6

Outside leaders to the frost line shall be one size larger than required in the above table.

Gutters 8 inches or over in width on new buildings shall be hung with wrought-iron hangers of approved type.

The above sizes of rain leaders are based on diameter of circular rain leaders, and gutters based on semicircular sheet-metal gutters with the top dimension given and other shapes shall have the same sectional area.

SEC. 125. INSIDE CONDUCTORS.—When placed within the walls of any building or run in an inner or interior court or ventilating pipe shaft, all conductors or roof leaders shall be constructed of cast iron or of galvanized wrought iron or steel pipe.

SEC. 126. OUTSIDE CONDUCTORS.—When outside conductors or down spouts of sheet metal are connected with the house drain, they

shall be so connected by means of not less than one length of cast-iron pipe extending vertically at least 1 foot above the grade line.

Along public driveways without sidewalks they shall be placed in niches in the walls, protected by wheel guards, or enter the building through the wall at a 45° slope at least 12 feet above the grade.

SEC. 127. DEFECTIVE CONDUCTOR PIPES.—When an existing sheet-metal conductor pipe within the walls of any building becomes defective, such conductor shall be replaced by one which conforms to this code.

SEC. 128. VENT CONNECTIONS WITH CONDUCTORS PROHIBITED.—Conductor pipes shall not be used as soil, waste, or vent pipes, nor shall any soil, waste, or vent pipes be used as conductors.

SEC. 129. OVERFLOWS.—Overflow pipes from cisterns, supply tanks, expansion tanks, and drip pans shall connect only indirectly with any house sewer, house drain, soil, waste, or vent pipe.

SEC. 130. SUBSOIL, FOUNDATION, CLEAR WATER, AND ABSORPTION TILE DRAINS.—Where subsoil drains are placed under the cellar floor or used to encircle the outer walls of a building, the same shall be made of open-jointed drain tile or earthenware pipe, not less than 4 inches in diameter, and shall be properly trapped and protected against back pressure by an automatic back-pressure valve accessibly located before entering the house sewer or drain. They may discharge through a cellar drain.

SEC. 131. SUBSOIL DRAINS BELOW SEWER LEVEL.—Subsoil drains below the main sewer level shall discharge into a sump or receiving tank, the contents of which shall be automatically lifted and discharged into the drainage system above the cellar through some properly trapped fixture or drain.

ARTICLE XII.—REFRIGERATOR, SAFE, AND SPECIAL WASTES

SEC. 132. FIXTURES PERMITTED TO CONNECT.—No waste pipe from a refrigerator or ice box floor drain, or any other receptacle where food is stored shall connect directly with any house drain, soil, or waste pipe. Such waste pipes shall in all cases empty into an open sink that is properly supplied with water, connected, trapped, and vented, the same as other fixtures, or they may discharge into a down spout or rain leader trap located inside the building or into a cellar floor drain, but their ends must be left open. Such waste connections shall not be located in inaccessible or unventilated cellars.

SEC. 133. REFRIGERATOR WASTES.—Refrigerator-waste pipes shall be not less than $1\frac{1}{4}$ inches for 1 opening, $1\frac{1}{2}$ inches for 3 openings, and for 4 to 12 openings must be not less than 2 inches, and shall have at each opening a trap, and clean-out at angles, so arranged as properly to flush and clean pipe. Such waste pipes shall be continued not less than full size through the roof, except where such fixtures are located in the basement or first floor.

SEC. 134. OVERFLOW PIPES AND MOTOR EXHAUSTS.—Pipes from a water-supply tank or exhaust from a water lift shall not be directly connected with any house drain, soil, or waste pipe. Such pipe shall discharge upon the roof or be trapped into an open fixture or discharge as for refrigerator wastes.

ARTICLE XIII.—MAINTENANCE

SEC. 135. DEFECTIVE FIXTURES.—All installed fixtures found defective or in an insanitary condition shall be repaired, renovated, replaced, or removed within 30 days upon written notice from the proper administrative authorities.

SEC. 136. TEMPORARY TOILET FACILITIES.—Suitable toilet facilities shall be provided for the use of workmen during the construction of any building. These toilet facilities shall be maintained in a sanitary condition.

ARTICLE XIV.—INSPECTIONS AND TESTS

SEC. 137. INSPECTIONS.—All piping, traps, and fixtures of a plumbing system shall be inspected by the proper administrative authority to insure compliance with all the requirements of this code and the installation and construction of the system in accordance with the approved plans and the permit.

SEC. 138. NOTIFICATION.—(a) It shall be the duty of the plumber to notify the proper administrative authority and the owner, or his authorized agent orally, by telephone, or in writing, not less than eight working hours between the hours of 8 a. m. and 4 p. m before the work is to be inspected or tested.

(b) It shall be the duty of the plumber to make sure that the work will stand the test prescribed before giving the above notification.

(c) If the proper administrative authority finds that the work will not stand the test, the plumber shall be required to renotify as above and to pay the sum of ——— dollars for each renotification.

(d) If the proper administrative authority fails to appear within 24 hours of the time set for each inspection or test, the inspection or test shall be deemed to have been made, and the plumber required to file an affidavit with the proper administrative authority that the work was installed in accordance with the code, the approved plans and permit, and that it was free from defects and that the required tests had been made and the system found free from leaks; also whether the owner or his authorized agent was present when such inspection or test was made, or was duly notified.

(e) At the time the permit is taken out a written waiver by the owner of notification may be filed with the proper administrative authority.

SEC. 139. MATERIAL AND LABOR FOR TESTS.—The equipment, material, power, and labor necessary for the inspection and test shall be furnished by the plumber.

SEC. 140. SYSTEM TESTS.—All the piping of a plumbing system shall be tested with water or air. After the plumbing fixtures have been set and their traps filled with water the entire drainage system shall be submitted to a final air-pressure test. The proper administrative authority may require the removal of any clean-outs to ascertain if the pressure has reached all parts of the system.

SEC. 141. METHODS OF TESTING.—(a) *Water test.*—The water test may be applied to the drainage system in its entirety or in sections. If applied to the entire system, all openings in the piping

shall be tightly closed, except the highest opening above the roof and the system filled with water to the point of overflow above the roof.

If the system is tested in sections, each opening shall be tightly plugged, except the highest opening of the section under test, and each section shall be filled with water; but no section shall be tested with less than a 10-foot head of water or a 5-pound pressure of air. In testing successive sections at least the upper 10 feet of the next preceding section shall be retested, so that no joint or pipe in the building shall have been submitted to a test of less than a 10-foot head of water or a 5-pound pressure of air.

Under any test the water or air pressure shall remain constant for not less than 15 minutes without any further addition of water or air.

(b) *Air test.*—The air test shall be made by attaching the air compressor or test apparatus to any suitable opening and closing all other inlets and outlets to the system, then forcing air into the system until there is a uniform pressure sufficient to balance a column of mercury 10 inches in height or 5 pounds per square inch on the entire system. This pressure shall be maintained for 15 minutes.

(c) *Final air test.*—The air machine shall be connected to any suitable opening or outlet and an air pressure equivalent to 1 inch water column shall be applied and left standing at least 15 minutes. If there is no leakage or forcing of trap seals indicated by the fluctuation of the drum, float, or water column, the system shall be deemed air-tight.

SEC. 142. ORDER OF TESTS.—The tests may be made separately, as follows:

(a) The house sewer and all its branches from the property line to the house drain.

(b) The house drain and yard drains, including all piping to the height of 10 feet above the highest point on the house drain, except the exposed connections to fixtures.

(c) The soil, waste, vent, inside conductor, and drainage pipes which would be covered up before the building is inclosed or ready for completion. The tests required for (b) and (c) may be combined.

(d) The final test of the whole system.

(e) After each of the above tests has been made and proved acceptable the proper administrative authority shall issue a written approval.

SEC. 143. COVERING OF WORK.—No drainage or plumbing system or part thereof shall be covered until it has been inspected, tested, and approved as herein prescribed.

SEC. 144. UNCOVERING OF WORK.—If any house drainage or plumbing system or part thereof is covered before being regularly inspected, tested, and approved, as herein prescribed, it shall be uncovered upon the direction of the proper administrative authority.

SEC. 145. DEFECTIVE WORK.—If inspection or test shows defects, such defective work or material shall be replaced within three days and inspection and test repeated.

SEC. 146. HOUSE SEWER AND HOUSE DRAIN TESTS.—The house sewer and house drain shall be tested with water or air. The water test shall have not less than a 10-foot head of water and the air test not less than a 5-pound pressure. All alterations, repairs, or extensions, which shall include more than 10 feet, shall be inspected and tested.

SEC. 147. CONDUCTOR PIPES.—Conductor pipes and their roof connections within the walls of buildings, or conductor branches on the outside system where such branches connect with the house drain or are less than 3 feet from the wall of the building, shall be tested by the water or air test. Conductor branches on the outside system may be tested in connection with the house drain.

SEC. 148. STABLE AND STABLE-YARD DRAIN TEST.—If a stable or any part of a stable be used for human habitation, the same inspections and tests of plumbing and drainage systems thereof shall be made as in the case of an ordinary dwelling. Otherwise, all stable and stable-yard drains shall be inspected, but need not be tested.

SEC. 149. GARAGE AND DRAINAGE SYSTEM.—For a garage or any part of a garage the same tests and inspection of the plumbing and drainage system thereof shall be made as in the case of an ordinary dwelling.

SEC. 150. TEST OF WATER-DISTRIBUTION SYSTEM.—Upon the completion of the entire water-distribution system it shall be tested and proved tight under a water pressure not less than the maximum working pressure under which it is to be used.

SEC. 151. CERTIFICATE OF APPROVAL.—Upon the satisfactory completion and final test of the plumbing system a certificate of approval shall be issued by the proper administrative authority to the plumber to be delivered to the owner.

SEC. 152. AIR TEST OF DEFECTIVE PLUMBING.—The air test shall be used in testing the sanitary condition of the drainage or plumbing system of all buildings where there is reason to believe that it has become defective. In buildings condemned by the proper administrative authority because of insanitary conditions of the plumbing system the alterations in such system shall not be considered as repairs, but as new plumbing.

SEC. 153. INSPECTIONS AND TESTS NOT REQUIRED.—No tests or inspections shall be required where a plumbing system or part thereof is set up for exhibition purposes and is not used for toilet purposes and not directly connected to a sewerage system; nor after the repairing or replacing of an old fixture, faucet, or valve by a new one (to be used for the same purpose); nor after forcing out stoppages and repairing leaks.

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